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SCIENCE TEXT-BOOKS

LABORATORY GUIDE
IN
GENERAL CHEMISTRY.

BENTON.

D. C. HEATH & Co.

A
LABORATORY GUIDE
FOR A
TWENTY WEEKS COURSE
IN
GENERAL CHEMISTRY

CONTAINING

DETAILED INSTRUCTIONS FOR THE SUCCESSFUL PERFORMANCE
OF OVER 150 EXPERIMENTS IN GENERAL INORGANIC
CHEMISTRY, AND USEFUL TABLES OF REFERENCE FOR PUPIL AND TEACHER.

BY

GEORGE WILLARD BENTON, A.M.
INSTRUCTOR IN CHEMISTRY, HIGH SCHOOL, AND CHEMIST FOR THE CITY OF
INDIANAPOLIS, IND.

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PREFACE.

THE LABORATORY METHOD of teaching chemistry is thoroughly established. Its superiority over the old lecture methods has been and is being constantly demonstrated, in the increased use of text-books and manuals introducing chemical principles in simple form, and in the encouragement of teachers who see in the Laboratory the means of high development on approved pedagogical grounds.

This method implies the adaptation of the chemical course to the capacity of the average pupil, not only as to apparatus and chemicals, but in the far more important matter of the comprehension of results and the development of great principles. Simplicity in the former respect is attained by the use of materials whose handling is least involved and complex. Success in reaching results and conclusions lies in the correct use of the facts observed.

In the course, of which these experiments are a part, little use is made of the lecture-room experiment and only an occasional lecture is introduced as a rounding-up or development step, *following* the work in laboratory and quiz. The experiments themselves are simple, but reasonable. The book is not a compilation, except in so far as all books on the elements of chemistry are, of necessity, compilations. Again, it is not a book for the teacher, but eminently one for the pupil. A good teacher will be able to furnish a bright pupil with any amount of supplementary work. The teacher's business in the laboratory is to direct, the pupil's, to do the work. It is believed that contact with the *thing* itself is essential for the best development; and it is equally essential that the sequence of fact and conclusion should be attained by the natural process of observation followed by discussion. In this belief the pupil is led to discover, as far as practicable by purely inductive processes, the main truths of the science, the question marks occurring at intervals inviting to the making of many of his own questions. Experimentation is followed by quiz and discussion, with a sprinkling of recitation from the text, not omitting references to reliable authorities.

In this way the pupil not only is unconsciously led to adopt methods of logical thinking, and to come into touch with chemical principles and methods of determining them, but, on the other hand, is saved the distasteful task of *repeating* experiments which have been already seen and discussed in the lecture-room. Such repetition would necessarily lack the enthusiasm and zest of originality; the ingenuity of the pupil would constantly suffer from dearth of action, and the whole work become mechanical.

The use of the note-book should be confined to the laboratory, that its statements, right or wrong, may be free from "bookish" phrases, and represent the pupil's own work. The form of the notes must necessarily vary with the experiment and the individuality of pupil and teacher. Neat, concise, logical, and complete notes should be insisted upon from the start, and will soon become the habit of the careful student.

The favorable criticisms of many officers and teachers in High Schools throughout this and other States, have induced the writer of these experiments to put them in permanent form, in the hope that their use may be extended, and their influence upon elementary chemical education may be marked and of a high order.

It is a pleasure at this time to acknowledge the assistance received from Mr. JAMES. H. SHEPARD, author of "Shepard's Chemistry," from whose admirable book much of the material has been adapted, and to which reference is constantly made; from Mr. HUGH BRYAN, Assistant in Chemistry, Indianapolis High School, in the preparation of the manuscript; and Mr. M. E. CROWELL, Instructor in Physics, of the same school, in the criticism of manuscript and proof. The obligations of the writer are also due Mr. E. F. HOLDEN, of Melrose, Mass.; Mr. T. PHOENIX, New Britain, Conn.; Mr. T. W. SMITH, Indianapolis High School No. 2; Mr. W. W. GRANT, Providence, R. I.; Mr. M. A. BRANNON, Fort Wayne High School, and many others who have by their criticisms aided in the presentation of the book in its present form.

G. W. B.

INDIANAPOLIS, Aug. 10, 1893.

FOR THE PUPIL.

1. This book must not be taken from the laboratory without permission. Statements written in it must represent your own laboratory work and conclusions.

2. Write in ink on the fly-leaf of the book, your name, division, desk, and drawer in the laboratory.

3. Each pupil is held responsible for the condition of his desk and apparatus, and is required to leave everything clean and in good order.

4. Each pupil should have a good pencil, a clean towel, old cloths for cleaning purposes, an apron, a tin or other metal box with matches, and blank paper for miscellaneous use.

5. To clean a test-tube, rinse it thoroughly with water using a brush if necessary. If this does not leave it clean, use a little conc. hydrochloric or nitric acid, or if necessary, both at once, and then rinse with plenty of water. A tube will clean with one-tenth the time and trouble if not allowed to stand until dry. Brushes must not be used with acids.

6. Pupils should be, and are, held responsible for all unnecessary or careless breakage.

7. Glassware should be drained, not wiped, on the inside. Before heating, tubes and flasks should be dry on the outside.

8. In heating test-tubes, hold them in the fingers, using the test-tube holder only when necessary. Keep the tube constantly moving. In the case of solids which may melt or give up water, heat should be applied gradually, to avoid breaking.

9. Pupils are cautioned not to mix chemicals or to attempt experiments on their own account.

10. In generating gases, care should be taken to have all joints tight, and corks in good condition.

11. In using reagent bottles, never lay the stoppers down. Hold them between the first and second fingers and replace at once.

12. Tubes to which reagents are to be added, and in which liquids are to be measured, should be held on a level with the eye.

13. In applying reagents, especially with work in metals, add the reagent a drop at a time. Remember that more may be added, but none taken out of your mixture.

14. Nothing should be put into reagent bottles, not even stirring rods or litmus paper. Never pour back a reagent once removed from its bottle.

15. Reagents found on the side table are for general use, and must not be taken to individual desks.

16. Only the finer-grained solid matters and liquids are to be put into the sink. Flush well with water, especially when acids are thrown out. Larger solid refuse, burned matches, etc., must be put into the jars provided for the purpose.

17. Before beginning the work of an experiment,

read the directions through carefully, get the necessary material at hand, and then follow each step intelligently. Do not attempt anything you do not understand. Ask for an explanation.

18. You will have enough to do, without attending to the work of your neighbor.

19. In experimenting, use your own hands; in observing, use your own eyes; in reasoning, use your own mind and common sense.

20. In making your notes, be original and clear. Emphasize important facts; notice minor ones. Use symbols and formulæ wherever possible, in case the name of a substance appears more than once in the same experiment.

21. Equations should be expressed in symbols and formulæ, and should not only be completed but balanced. Constant use of the table of elements appended will aid in equation work.

22. References to text-books should be consulted only *after* performing the experiment.

23. Accidents, as burns, etc., should receive prompt attention from the instructor, to avoid annoying and perhaps serious consequences.

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SUBJECTS TREATED BY EXPERIMENTS.

THE APPENDIX.

CHEMISTRY EXPERIMENTS.

MEASUREMENTS.

Experiment 1. — Capacity of a Test-Tube. Draw in your note-book two vertical parallel lines, 15^{cm} (about 6 in.) long, and $1\frac{1}{2}^{cm}$ (about $\frac{1}{2}$ in.) apart.

Connect the upper ends by a straight line, the lower by a curved line. This figure represents the outline of a common test-tube.

Draw a line 10^{cm} from the bottom, and parallel to the top. Mark this 20^{cc}.

From this data show by measurement the part of the tube filled by 10^{cc}, 5^{cc}, and 1^{cc} of a liquid.

Would you measure from the extreme bottom of the curve in estimating capacity? Give reason for your answer.

Experiment 2. — To approximate Quantities of a Liquid. Compare a test-tube from your rack with the diagram traced in Exp. 1. Pour water into the tube, noting the quantity required to reach the 1^{cc}, 5^{cc}, 10^{cc}, and 20^{cc} marks in succession, measuring the depth and comparing with the diagram.

Repeat the experiment until you are able to measure quantities with reasonable accuracy.

Do you find all the tubes of the same diameter? If not, what allowance must be made for these variations?

Note the curved surface of the liquid in the tube. It is called the meniscus. (?)

It is customary in measuring liquids to measure from the lower surface of the meniscus.

PHYSICAL AND CHEMICAL CHANGES.

Experiment 3. — Place in a test-tube 10^{cc} of H_2O, and holding over the flame of the Bunsen burner, boil until only 5^{cc} remain. (?)

Note the liquid condensed on the sides of the tube. What is it?

Have the changes just noted resulted from chemical or physical action?

Experiment 4. — Place a crystal of iodine in a test-tube and heat it moderately as long as a violet vapor arises from the bottom of the tube. Let the tube cool.

Examine the small crystals collected near the top of the tube. Compare with the original crystal. (?)

Heat them a little. (?) Let the tube cool. (?) Heat the crystals again. (?)

Are you convinced that the small crystals are of the same composition as the original crystal?

Does this show chemical or physical action?

Experiment 5. — Examine a fragment of marble, $CaCO_3$. (?) Note taste, odor, etc., if any. (?)

Place the marble in a tube and heat it. (?)

When the tube has cooled, add about 5^{cc} of H_2O, and boil. (?)

Now add three or four drops of concentrated HCl. (?) Insert a lighted match into the mouth of the tube. (?)

Place in a test-tube 5^{cc} of calcium hydroxide solution, $Ca(OH)_2$, and by means of a delivery tube and cork pass some of the gas evolved from the marble through the $Ca(OH)_2$ solution. (?)

Were the changes noted due to chemical change? Give reason.

Experiment 6. — Place a small piece of sheet copper in a tube and add about 5^{cc} of dilute nitric acid, HNO_3. (?) Note the color of the liquid. (?)

Take two drops of the liquid on a piece of glass and warm *gently*, holding the glass in the hand over the flame. (?)

Compare the product with the original copper. (?)

Indicate which process is chemical and which is physical.

VARIOUS WAYS OF INDUCING CHEMICAL CHANGE.

Experiment 7. — Contact of Chemical Substances. Mix about .2 gram each of powdered potassium chlorate, $KClO_3$, and sugar in an evaporating dish.

Drop into the mixture 4 or 5 drops of concentrated H_2SO_4. (?)

Would the first step of Exp. 6 illustrate the same principle?

Experiment 8. — Change produced by Heat. Hold a strip of magnesium in your nippers. Bring the end into the flame until it becomes ignited. (?) Hold the ribbon while burning over a piece of paper.

Examine the product. (?)

Compare the product with the original magnesium. (?)

Experiment 9. — Change produced by Solution. Mix in a dry evaporating dish a small quantity of anhydrous (?) ferrous sulphate, $FeSO_4$, and an equal quantity of potassium ferrocyanide, K_4FeCy_6.

Now moisten the mixture with water. (?)

Compare with the dry mixture. (?)

Dissolve in separate tubes a small quantity of the two original powders, using about 10^{cc} of water in each. (?)

Pour the solutions together. (?)

Note that it is the contact of the substances in water which causes the change.

SOME PROCESSES EMPLOYED IN CHEMISTRY.

Experiment 10. — Mechanical Solution. Place in a tube about .1 gram of common salt, NaCl. This will fill the curved part of the tube.

Add 10^{cc} of H_2O. Examine carefully and note any change.

Holding the tube in a good light, shake it gently. (?) Finally shake vigorously. (?)

Is the disappearance of the salt due to a physical or chemical change?

Problem. If 1^{cc} of H_2O weighs 1 gram, what per cent of NaCl is contained in the above solution?

Experiment 11. — Evaporation. Pour a few drops of the salt solution upon a glass plate; hold over the flame and warm *gently* until the residue is dry. (?) Do not let the liquid boil.

What has become of the water?

Examine the residue with a magnifying glass. (?) Note the taste. (?) Is it still salt?

Is your answer to the last question in Exp. 10 confirmed?

Experiment 12. — Chemical Solution. Pour 1^{cc} of dilute H_2SO_4 on a small piece of zinc in a tube. (?) Heat gently. (?) Compare Exp. 10.

After action ceases, evaporate a few drops of the solution nearly to dryness. (?) Compare Exp. 11.

Examine the remaining substance with a magnifying glass. (?) Compare with the original zinc. (?)

Distinguish between ordinary or mechanical solution and chemical solution.

Experiment 13. — Precipitation. To 1^{cc} of the salt solution obtained in Exp. 10, add 10^{cc} of H_2O.

Hold the tube in a good light and add about 5 drops of a solution of silver nitrate, $AgNO_3$, a drop at a time, and note the effects. (?) The white curdy precipitate is silver chloride, $AgCl$.

Reaction: $NaCl + AgNO_3 = AgCl + NaNO_3$.

The silver of the $AgNO_3$ has united with the chlorine of the $NaCl$ to form the *insoluble* solid $AgCl$, thus removing the chlorine from the salt solution, and the silver from the silver nitrate solution.

What is the object of precipitation? Would evaporation answer the same purpose?

Define precipitation; precipitate.

The liquid remaining after precipitation is called the menstruum.

Preserve the contents of the tube for Exp. 14.

Problem. What per cent of salt was contained in the salt solution to which the $AgNO_3$ was added?

Experiment 14. — Filtration. Fold a filter, place in a funnel, and moisten with clear water. Support the funnel over a clean tube.

Shake the tube containing the precipitate prepared in the last experiment, and holding a glass rod vertically over the funnel and near the filter, pour the contents of the tube against the rod. Of what advantage is the rod?

Examine the liquid which passes through the filter. (?) What has been accomplished? The clear liquid is called the filtrate. Would it be possible to remove all the silver from a solution of silver nitrate by treating it as in Exps. 13 and 14? Give reasons for answer.

Experiment 15. — Decantation. Treat 5^{cc} of the salt solution with about 5 drops of $AgNO_3$ solution as before. (?) Compare Exp. 13.

Shake vigorously and allow to stand a few moments. The precipitate settles.

Now pour off the clear liquid leaving the precipitate in the tube. This process is called decantation. Compare Exp. 14.

Which takes the less time and which is the more accurate?

Now take in a clean tube 1^{cc} of barium chloride solution, $BaCl_2$; dilute to 5^{cc} with H_2O and add two drops of dil. H_2SO_4. (?)

Shake vigorously and let stand as before. (?)

Could decanting always take the place of filtering? Why?

COMPARISON OF ELEMENTS AND COMPOUNDS.

Experiment 16. — The Element. Examine a piece of platinum wire. Hold the wire in the non-luminous, or hot flame. (?) Remove from the flame and examine. Is the wire changed by heating?

Place another piece of the wire in a test-tube. Add 2^{cc} of conc. HNO_3. (?) Heat to the boiling point. (?)

Wash the wire well by filling the tube twice with water and *pouring off again slowly*, in order not to wash away the wire.

Add as before, 2^{cc} of conc. HCl. (?) Heat until near the boiling point. (HCl should not be boiled, as it drives off the acid.) (?)

Have you succeeded in reducing the platinum to simpler substances? Define an element.

Experiment 17. — The Compound. Take in a clean dry test-tube a piece of match stick about ¼ in. long.

Heat gradually and evenly, rolling the tube in the fingers until the stick ceases to undergo change. (?)

Note the liquid produced, also the smoke and other products. (?)

Have you succeeded in producing simpler substances out of the pine stick?

Remove and examine a piece of the charred product. (?) Note its weight.

Place the charcoal thus prepared on a piece of platinum foil, and holding with your nippers, subject it to the heat of the Bunsen flame until no further change is noted. (?)

Compare results in this experiment with the result in Exp. 16. (?)

Experiment 18.—The Compound. Place in an evaporating dish a few grains of granulated sugar, $C_{12}H_{22}O_{11}$.

Drop on the sugar two or three drops of strong sulphuric acid, H_2SO_4. (?) Warm gently. (?)

What is the black substance produced?

Note the increased quantity of liquid. What is it?

Reaction:

$$C_{12}H_{22}O_{11} + H_2SO_4 = 12\,C + 11\,H_2O + H_2SO_4.$$

Explain the equation. Define a compound.

MECHANICAL MIXTURES.

Experiment 19.—Mix intimately about equal parts of fine iron filings and flowers of sulphur. Compare the mixture with the two ingredients. (?)

Try to separate the iron and sulphur by means of a magnet. (?)

Cover a small quantity of the mixture with carbon disulphide, CS_2, on a watch-glass.

Drain the liquid onto a glass plate and let it evaporate. (?) Examine the remaining substance. (?)

Add to a very small quantity of flowers of sulphur enough CS_2 to dissolve the sulphur. Place the solution on a glass plate and allow to evaporate. (?)

Compare with the previous product of evaporation. (?)

Have you succeeded in separating the iron and sulphur by both processes?

Were they physical or chemical processes?

Experiment 20.—Mix equal parts of flowers of sulphur, potassium chlorate, $KClO_3$, and charcoal. Com-

pare the mixture with the original substances. (?) Is it possible to still distinguish the particles of each?

Place a filter in a funnel, put a small quantity of the mixture on the filter and wash with about 2^{cc} of water. Catch the filtrate in a clean tube.

Pour three or four drops upon a glass plate and evaporate with a low heat. (?)

Taste the substance. Taste some $KClO_3$. (?)

What remains on the filter?

Wash the residue on the filter with about $\frac{1}{2}^{cc}$ of CS_2. Collect the filtrate on a glass plate and evaporate without heat. (?) Compare Exp. 19. (?) What remains on the filter?

Have the three substances been separated by chemical or by mechanical means?

Define a mechanical mixture.

TO PRODUCE A CHEMICAL COMPOUND FROM A MECHANICAL MIXTURE.

Experiment 21. — Place in a tin-box cover about a teaspoonful of the mixture of iron and sulphur prepared in Exp. 19.

Hold the cover in your nippers and heat persistently in the hot flame (under the hood) until a glow has passed over the mixture. Some of the sulphur burns with a blue flame ($S + O_2 = SO_2$. Note the odor), while the remainder combines with the iron.

Reaction: $Fe + S = FeS$. Some of the iron may remain uncombined.

Examine and compare the cooled product with the original mixture. (?) Try it with a magnet. (?)

Moisten with one or two drops of H_2SO_4. (?) Note the odor.

When H_2SO_4 is brought into contact with FeS the odor of hydrogen sulphide is noticed. (?)

Have we evidence that the iron and sulphur combined?

PREPARATION AND PROPERTIES OF OXYGEN.

Experiment 22. — Preparation from Mercuric Oxide, HgO. Take about .5 in. of mercuric oxide, HgO, in a tube.

Heat the tube gradually and evenly, rolling it in the fingers. Care must be taken not to melt the tube, but it must be highly heated.

When hot, and continually held in the flame, plunge into the tube, without touching the contents, a glowing splinter of pine. (?)

Have you any evidence of chemical change taking place?

Examine the sides of the tube. (?) Is mercury collected there?

Reaction: $HgO = Hg +$ Explain the effect on the glowing pine.

Is oxygen solid, liquid, or gaseous?

Experiment 23. — Preparation from $KClO_3$. Place in a test-tube a few crystals of potassium chlorate, $KClO_3$.

Heat carefully. The crystals soon melt, and the liquid appears to boil. In fact, oxygen is being evolved.

Drop into the tube a piece of match stick, and continue to heat the tube enough to keep up the evolution of the gas. (?)

How does the action compare with that of Exp. 17?

What evidence have you that oxygen has been prepared?

Experiment 24. — To collect a Gas over Water. Fill the pneumatic trough with water until the shelf is submerged. Fill a wide-mouth bottle with water, cover with a glass plate, and holding the cover firmly, invert the bottle and place on the shelf over the opening.

Why does the water remain in the bottle?

Hold the end of a delivery tube beneath the opening in the shelf and blow gently through the tube. Bubbles of air will rise through the opening and gradually fill the bottle. Explain the change.

Other gases are collected over water in the same way, the delivery tube being attached by means of a cork to the vessel in which the gas is being generated.

Experiment 25. — To collect Several Bottles of Oxygen. Fit a test-tube with a good cork and delivery tube. Arrange four bottles to collect the gas over water.

Place in the tube 10^{cc} of a mixture of four parts of $KClO_3$ and one part of MnO_2. Replace the cork in the tube and heat the mixture gently, passing the gas evolved into the bottles in succession.

To avoid loss, care should be taken to heat the mixture only sufficiently to cause the gas to come off moderately.

When the bottles have been filled, remove the delivery tube from the water at once, as the water may be drawn back into the test-tube as it cools.

The gas thus collected is to be used in the four following experiments.

Reaction: $KClO_3 + MnO_2 = KCl + MnO_2 + ?$

By reference to the equation it will be seen that the MnO_2 is left after the reaction is complete.

Compare the amount of heat necessary in this experiment with that required in Exp. 23. (?) Compare the ingredients used. (?)

What inference may be drawn concerning the influence of the MnO_2. (?)

The MnO_2 may be recovered by washing well with water and filtering. It remains on the filter.

Experiment 26. — To burn Charcoal in Oxygen. Remove a bottle of oxygen from the pneumatic trough and stand it upright on the table, keeping the bottle covered with the glass plate. The bottle should contain a little water, to prevent breaking in case the charcoal should fall.

Make a small loop at the end of a wire and place in it a piece of charcoal about the size of a pea.

Heat in the flame until lighted, and then plunge the charcoal into the gas. (?) Compare Exp. 23. (?)

What is the product of the combustion? $C + 2O = ?$

Experiment 27. — To burn Iron in Oxygen. Wind a piece of fine iron wire into the form of a spiral by means of a round pencil. Make a small loop at the end as large as a pin-head.

Holding the wire in a pair of nippers, heat the loop and coil until red hot, plunge while hot into some flowers of sulphur, and then quickly into the bottle of oxygen and replace the cover, as the gas will otherwise escape. (?) As before, the bottle should contain some water.

Does iron burn readily in air? Is oxygen an active supporter of combustion?

Equation: $3Fe + 4O = Fe_3O_4$.

Experiment 28. — To burn Phosphorus in Oxygen. Place on the table another bottle of oxygen, containing a little water, and covered.

Take a small piece of dry phosphorus in a combustion spoon. (Phosphorus must never be handled with the fingers. Use nippers. It is kept under water to prevent contact with the oxygen of the air.)

Ignite the phosphorus by holding the spoon in the flame for an instant. Quickly plunge the spoon into the bottle and replace the cover. (?) Phosphorus pentoxide is formed. Reaction: $2P + 5O = P_2O_5$.

Let the bottle stand for a few moments. (?) $3H_2O + P_2O_5 = 2H_3PO_4$. H_3PO_4 is phosphoric acid. Try the liquid with litmus paper. (?) What has happened to the white fumes?

Experiment 29. — To burn Magnesium in Oxygen. Hold a strip of magnesium ribbon in your nippers. Ignite and plunge the ribbon into a jar of oxygen. (?)

Compare the product with the magnesium. Are any black particles mixed with the white?

Equation: $Mg + O = ?$

Magnesium oxide is a white powder. Should there be any black particles? Compare the burning of magnesium in air (Exp. 8) with that in oxygen.

PHENOMENA OF COMBUSTION.

Experiment 30. — Structure of a Flame. Bring a piece of cardboard, held horizontally, against the wick of a burning candle.

Quickly bring the card to a vertical position against the wick. The flame is outlined on the card, and pre-

sents a longitudinal section. Remove the card quickly to prevent burning.

Now bring a fresh card horizontally down over the flame, and nearly touching the wick. A cross section of the flame is produced.

Now examine the flame closely. Note the cup-shaped blue or colorless portion surrounding the wick; the cone-shaped continuation of the colorless zone above the wick; the surrounding envelope of luminous flame and the very thin envelope of non-luminous flame surrounding all.

The sections on the cardboard give only two distinct zones. (?)

Draw a diagram indicating the zones of no combustion, incomplete and complete combustion.

Experiment 31. — Structure of Flame continued. Hold a pine splinter across the top of the wick of a lighted candle.

When the stick begins to char, quickly remove it and stop its burning. Observe both upper and under surfaces of the stick. (?)

Is this result consistent with what has already been found?

Experiment 32. — Structure of Flame continued. Hold the lower end of a glass tube in the centre of the luminous flame, the tube slanting upward at an angle of about 45 degrees. Hold a lighted match at the upper end of the tube. (?)

What is the condition of the inner part of the flame? Why?

Experiment 33. — Source of the Light of the Luminous Flame. Hold a cold dry iron spoon down in the luminous flame for a few seconds, but not long enough to get the spoon red hot. Remove and examine the spoon. (?)

Notice the black smoke rising the instant the spoon touches the flame. (?)

Now open the holes at the base of the burner. (?) Hold the spoon with the black deposit on it in the non-luminous flame, and note effect. (?)

What was the black substance? What causes the light?

Why does the light only appear when the holes at the base are closed? (?)

Hold the cold spoon in the flame of a candle as before. (?) What is the deposit?

Hold the spoon in the non-luminous flame of the burner as before. (?) Is the light of the candle due to the same cause?

Carbon and hydrogen are the fuels in both cases. One is solid, the other gaseous. (?)

When they burn in oxygen, what are the products? Reactions: $C + O_2 = ?$; $H_2 + O = ?$ Both products of combustion are colorless. This explains the fact that a flame burning quietly has a well-defined outline and no visible products.

Experiment 34. — Air and Combustion. Invert a common glass tumbler over a candle flame, excluding the outside air. (?) Explain. Has oxygen any connection with that action?

Try the same thing again, except that this time hold the tumbler so that the candle may be near its side, and free access of air be allowed. (?) Explain.

Experiment 35. — Ventilation and Combustion. Stand a lamp chimney down over a lighted candle completely excluding air from below. Note the effect on flame.

Raise the chimney a little from the support and allow free circulation of air. Any effect? Explain.

Still holding the chimney free from the support, place a strip of glass over the top. (?) Explain.

What do you learn about draughts and ventilation in this experiment?

Experiment 36. — Ventilation and Combustion continued. Hang a strip of tin or zinc, about 4 to 6 in. long, from the top of a lamp chimney, to partition the chimney into two parts.

Bring the chimney, thus prepared, firmly down over a lighted candle, excluding the air from below, as before. (?) Bring a strip of lighted touch paper over the chimney. (?)

Why does the candle continue to burn? How does the touch paper aid in explaining the action?

THE BLOWPIPE. — OXIDIZING AND REDUCING FLAMES.

Experiment 37. — The Oxidizing Process. Make a small loop at the end of a platinum wire. Heat the wire, dip it into borax, and heat with the blowpipe until a colorless bead is formed.

Touch the bead while hot to a *very small particle* of manganese dioxide, MnO_2. Heat strongly for a moment in the oxidizing flame.

Hold the bead up to the light, and note the color while hot, and when cold. (?)

What is meant by the term oxidizing? Does oxygen come from or go to the bead in this experiment? How? How is the oxidizing flame produced?

Experiment 38. — The Reducing Process. Heat the red-colored bead produced in Exp. 37 persistently in the reducing flame until the bead becomes clear.

The flame contains an excess of carbon and hydrogen, highly heated. Both elements have a strong affinity for oxygen. Hence the oxidized bead heated in the presence of carbon and hydrogen is caused to give up its oxygen. This is called reduction. Compare oxidation. (?)

Experiment 39. — Dip a bead, while hot, into a solution of cobalt nitrate, $Co(NO_3)_2$.

First heat the bead in the oxidizing flame. (?) Then in the reducing flame. (?) Compare the action with that observed in Exps. 37 and 38. (?)

From the results observed, would you think the bead test for a metal might be relied upon? Confirm your answer by reference to your text-book.

KINDLING TEMPERATURE.

Experiment 40. — Varies with the Substance. Place on a piece of porcelain, as far apart as possible, a small piece of phosphorus, one of sulphur, and one of iron. The substances must not touch.

Now place the porcelain on a tripod-stand, and heat as long as changes are noted, taking care that each substance on the dish is equally heated. (?)

Which burns first? Which last? Does the iron burn? Why not? Could it be made to burn? How?

Which has the lowest and which the highest kindling point?

Experiment 41. — Effect of cooling a Flame below the Kindling Point. Take a cold candle. Light a match and bring it slowly down over the wick until the tip of the wick is surrounded by a flame.

As soon as it lights, remove the match and note the changes which the candle and flame undergo until the flame burns uniformly and steadily.

A flame is a burning gas. Have you evidence of a gas being produced by the flame?

Now bring a piece of wire gauze slowly down over the flame. Note the effect on the flame, on the gauze, and above the gauze, as the flame-tip is reached. (?)

Continue to lower the gauze until it nearly touches the wick. Note appearances above and below the gauze as before. (?)

Hold a lighted match over the gauze and near enough to ignite any gas which may be rising from the candle. (?)

Will a gas burn when cooled below the kindling point? Read the description of the Davy safety lamp.

Experiment 42. — Place the Bunsen burner, with holes at the base closed, under the tripod and about two inches below the centre of the gauze covering. Turn on the gas and hold a lighted match above the gauze. (?)

Repeat the experiment, but this time hold the match below the gauze. (?) Compare Exp. 41. (?)

Under what circumstances would the gas burn above if lighted below only?

Experiment 43. — Make a coil by winding a piece of iron wire around a pencil ten or twelve times.

Bring the coil vertically down into a candle flame, so that the wick may pass up into the coil. (?)

Repeat the experiment, having heated the coil red hot in the flame of the Bunsen burner, and before the coil cools. (?)

Explain the difference in action. Compare Exps. 41 and 42. (?)

Experiment 44. — Ignition of Fuels Affected by Size of Particles. Hold the lighted burner in a horiontal position over an evaporating dish.

Sprinkle some fine iron filings over the flame. (?) Compare Exp. 27. (?)

Examine the filings which have fallen into the dish. (?) Which would burn more readily, the larger or smaller particles?

Since temperature and quantity of heat are not synonymous terms, and the same heat which would raise one particle 10 degrees would raise a particle $\frac{1}{10}$ as large 100 degrees (see Physics), it follows that a very small particle of iron falling through the flame would reach a very high temperature, while larger particles would not become even red hot. From this it follows that very fine dry dust becomes very combustible and easily rises to the point of ignition.

PREPARATION, PROPERTIES, AND TESTS FOR OZONE.

Experiment 45. — Preparation by Electric Discharge. Turn the wheel of the Holtz machine. At all angles and points a silent discharge may be noted.

Inhale a little air near one of the brushes. (?) The odor is that of ozone.

Compare the odor arising from a piece of phosphorus exposed to the air. (?)

The molecular formula of oxygen is O_2; that of ozone is O_3. Complete the equation $3O_2 = ?O_3$.

Problem. — If a molecule of ozone occupies the same space as a molecule of oxygen, how many cub. cent. of ozone would be obtained from 45^{cc} of oxygen?

Experiment 46. — Preparation by the Reduction of Potassium Permanganate. Take in a test-tube about 5^{cc} of a strong solution of potassium permanganate, $KMnO_4$.

Add a few drops of conc. H_2SO_4. Odor? Heat gently to boiling. Odor?

Dip a strip of bibulous (?) paper into a solution of potassium iodide, KI, and starch. Hold over, but not touching, the tube's mouth. (?) In case no immediate effect is noted, heat the tube again. (?)

Ozone liberates the iodine from the KI, and iodine when free attacks the starch, turning it blue. (?)

What reasons have you for inferring that ozone was set free?

Equations: (*a.*) $6KMnO_4 + 9H_2SO_4 = ?K_2SO_4 + ?MnSO_4 + ?H_2O + ?O_3$. (*b.*) $6KI + O_3 = ?K_2O + ?I$. The blue substance formed is called "Iodized Starch."

CHEMISTRY OF THE AIR.

Experiment 47.— It contains Moisture. Calcium chloride, $CaCl_2$, is deliquescent. (?) Place a small piece on a dry plate and expose to the air for a few moments. (?)

Experiment 48. — It contains Oxygen. (*a*) Take a small piece of metallic lead in a porcelain capsule. Place the capsule on a stand over the hot flame. (?)

When the lead melts, stir it with an iron wire until it becomes a powder. (?) The substance formed is an oxide of lead.

Try the same thing again, this time using a piece of zinc. (?) The product is yellow while hot, white when cold. It is zinc oxide, ZnO.

(*b*). Heat a piece of lead, as in (*a*), first covering the lead with a layer of borax. (?) The latter prevents the air coming in contact with the metal.

Is the same effect produced as when the air reached the metal?

Since in forming the oxides the air is made to give up oxygen, might air be deprived of oxygen by burning something? (See the preparation of nitrogen.)

PREPARATION AND PROPERTIES OF HYDROGEN.

Experiment 49. — Preparation from Sodium Amalgam. Put a piece of freshly prepared amalgam in a dish of water. Invert a small test-tube, filled with water, over the amalgam and collect the gas. Complete the equation $Na + H_2O = NaOH + ?$ What is collected in the tube?

Place a finger over the mouth of the tube and, holding it mouth down, remove from the water and plunge a blazing pine stick up into the tube. (?)

Does hydrogen burn or support combustion?

$NaOH$ is a white solid, very soluble in water.

Evaporate a few drops of the liquid in the dish.

(?) Touch the residue with a strip of moistened red litmus paper. (?)

Moisten a piece of the paper with the solution of NaOH found on the table. (?)

NaOH is alkaline. Has the water in the dish acquired alkaline properties?

Experiment 50. — Preparation from Zinc and Hydrochloric Acid. Arrange to collect two bottles of gas over water, as in Exp. 24. Place in a 4 oz. generating bottle enough granulated zinc to cover the bottom of the bottle. Cover the zinc with water.

Add about 5^{cc} of conc. HCl, quickly press the cork attached to the delivery tube into the bottle, and proceed to collect the gas as before.

Joints in the apparatus must be especially tight in this experiment, as hydrogen is very diffusible.

As soon as the gas is collected, wash the remaining zinc in the generating bottle, and leave in your evaporating dish. It may be used again.

Complete and balance the equation $Zn + HCl = ZnCl_2 + ?$ Gas collected will be used in the next two experiments.

Experiment 51. — Physical and Chemical Properties of Hydrogen. Examine the gas collected in Exp. 50. Note color (?), odor (?), etc.

Recall whether the bubbles of gas as they rose in the collecting bottles in Exp. 50 appeared to grow smaller or not. In case they grow rapidly smaller the gas is quite soluble. If they do not decrease perceptibly, it is comparatively insoluble. What can you say as to the solubility of this gas?

Now take a blazing pine splinter in one hand; remove a bottle of the gas, mouth down, and pass the blazing splinter up into the bottle of hydrogen. (?) Slowly withdraw the stick. (?)

Did the stick burn in the gas? Did the gas burn at the mouth of the bottle? Does hydrogen support combustion? Is it combustible?

If the hydrogen burns, what compound is produced? $H_2 + O = ?$

Experiment 52. — Diffusibility and Lightness of Hydrogen. Remove the remaining bottle of hydrogen with the cover glass, and stand it up on the table, mouth up, and covered.

Bring a second bottle, empty or filled with air only, down over the bottle of hydrogen, mouth down.

Remove the cover glass, and hold the two bottles firmly together.

After a half-minute slip the glass cover between the bottles again.

Present the mouth of the upper bottle to the flame. (?)

Now, remove the cover and present the lower bottle to the flame. (?)

Which bottle gave evidence of the presence of a larger proportion of hydrogen?

Show how the lightness and diffusibility of hydrogen would give rise to the phenomena noted.

Experiment 53. — Osmosis. Performed by the Teacher. Take a glass tube about 18 inches long and 1 inch in diameter. Seal one end with a thin (about $\frac{1}{8}$ inch) layer of plaster of Paris. Set it away until dry. The plaster plug must under no circumstances be moistened.

Fill the tube with hydrogen by the displacement of air. (?)

Place the open end of the tube in a beaker of water, vertically, and allow to stand, noting the level of the water from time to time. (?) Explain the rising and falling of the liquid in the tube.

Experiment 54. — Combination of Hydrogen and Oxygen. Performed by the Teacher. Fill a strong pint bottle, having a narrow mouth, with water.

Replace two-thirds of the water with hydrogen, and the remaining one-third with oxygen.

Let the bottle stand for a few moments to insure thorough mixing of the gases.

Place the thumb over the mouth of the bottle and stand it down on the table, tightly closed.

Remove the thumb and quickly bring a lighted match close to the mouth of the bottle. (?)

Notice the flame seen throughout the bottle at the instant of the explosion. What is the product of the combination? $2H + O = ?$ Explain the origin of the sound.

Experiment 55. — Comparison of Coal Gas and Hydrogen. Arrange to collect a bottle of gas over water.

Detach the burner from the gas-tube. Put the end of the tube under the mouth of the bottle of water and turn on the gas.

When the bottle is full, examine it. (?) Insert a blazing match as in Exp. 51. (?)

How does the action compare with that of Exp. 51? In what noticeable features are the two gases different?

WATER.

Experiment 56. — Generation of Water by Ordinary Combustion. Hold a clean, dry, and cold glass tumbler over a candle flame.

Notice the bottom and sides. (?) What is collected there? What chemical action has taken place? What physical action? Why should the tumbler be cold and dry?

Hold a cold, dry, glass plate for an instant over the hot flame of the Bunsen burner. (?)

If air contains oxygen (see Exp. 48) and the fuel constituents of the candle and gas are carbon and hydrogen (see Exp. 33), would water probably be in all cases a product of the burning of a gas which contained hydrogen? See the equation in Exp. 54.

Experiment 57. — Analysis of Water by Electrolysis. Performed by the Teacher. Fill the electrolysis apparatus with water acidulated with H_2SO_4 (1 to 20), and pass the current until enough gas has been collected to examine.

Note the volumes of the gases, and particularly which gas is in contact with respective poles of the battery. (?) Remove and carefully test each gas in succession. (?) Compare Exp. 54. (?)

Experiment 58. — Water of Crystallization. Heat a crystal of copper sulphate, $CuSO_4$, on an iron spoon. (?)

When completely changed, and cold, drop a little water on the powder. (?)

Put some of the powder into a test-tube and add 1^{cc} of water. (?)

Pour the contents of the tube into an evaporating dish and evaporate the liquid slowly without boiling. (?)

Compare the product with the copper sulphate with which you started. (?) Most crystals on examination will prove to contain more or less water. See text for formulæ of crystalline substances.

NITROGEN.

Experiment 59. — Preparation from Air. Float a tin box-cover on water in a pneumatic trough. Place on the float a small piece of dry phosphorus.

Ignite the phosphorus and bring an inverted glass tumbler quickly down over the pan, enclosing the air and burning phosphorus.

Another method. — Bend the handle of a combustion spoon to the shape of the letter V; place the phosphorus in the spoon, ignite, and bring an inverted wide-mouth bottle quickly down over the spoon, closing the mouth of the bottle with water as before.

In case the former process is used, it will be well to transfer the gas prepared from the tumbler to the wide-mouth bottle for further examination.

Why did a few bubbles of air escape at the outset of the experiment?

What element in the air combines with phosphorus to form white fumes? Confirm your answer by reference to Exp. 28.

While the phosphorus burns in the enclosed air, does the volume of the air remain the same? Estimate the new volume as compared with the old. Account for the fact noted.

Let the bottle stand until the fumes settle. The collected gas will be examined in the next experiment.

Experiment 60. — Properties. Remove the bottle of gas and place it upright upon the table, covered with the glass plate. Note color, odor, if any, and effect on litmus paper. Insert a blazing pine splinter. (?)

Pour the gas from the bottle. Does it rise or fall? Its sp. g. is 0.97. Which should it do?

What gas has been prepared and examined? Are its properties active or passive?

Moisten a strip of blue litmus paper in the water left in the pan. (?)

Balance the equation $P_2O_5 + H_2O = H_3PO_4$. Compare Exps. 28 and 48.

THE COMPOUND AMMONIA, NH_3.

Experiment 61. — Preparation from NH_4Cl and lime, CaO. Place in the palm of the hand, side by side, but not touching, about one grain of dry lime, CaO, and an equal bulk of ammonium chloride, NH_4Cl.

Note the odor, if any, of each. (?)

Mix the two substances with a finger and rub the mixture vigorously for a few moments. (?) Examine the mixture, — is it moist? Complete the equation $CaO + 2NH_4Cl = CaCl_2 + ? + ?$

Give such properties of ammonia as you have observed. Is it solid, liquid, gaseous, visible, invisible, odorless, etc.?

Experiment 62. — Preparation from a Solution of an Ammonium Salt. Place in a test-tube about 5^{cc} of a solution of ammonium chloride, NH_4Cl.

Add four or five drops of a solution of potassium hydroxide, KOH. (?) Heat gently. (?) Any odor?

Dip a clean glass stirring rod into hydrochloric acid, HCl, and bring it over the mouth of the tube. (?)

Hold a moistened strip of red litmus paper over the tube. (?)

Show by completing the following equation that ammonia was produced: $NH_4Cl + KOH = ? + ? + KCl$.

Other solutions of ammonium salts will yield ammonia in the same way.

Experiment 63. — Preparation from Organic Sources. Place a piece of hoof-clipping in a dry test-tube. Heat it carefully and gently, without burning. (?) Any odor? Hold over the tube a strip of moistened red litmus paper. (?) Is the presence of ammonia proved?

Hair, finger-nails, and many other organic substances will respond to the same test.

Experiment 64. — Simple Tests for Ammonia in Solution. Take about 5^{cc} of the solution to be tested in a test-tube. Add a few drops of potassium hydroxide, KOH. Heat the tube and contents gently. (?) Any odor? Is ammonia present? Why?

If it is present, was it free or combined before you added the potassium hydrate? Give reason for answer.

Hold over the mouth of the tube a strip of moistened red litmus paper, and heat as before. (?)

Does the change, if any, confirm your previous conclusion concerning the presence of ammonia. Explain.

Now hold over the mouth of the tube while heating a stirring rod moistened with hydrochloric acid, HCl. (?) Have you done a similar thing before? Was the product the same both times?

Are you convinced from the results of the three tests

that ammonia is present in the unknown solution? Which test do you consider the most delicate and convincing? Why?

If you were given a solid instead of a liquid to test, what would you have done first?

NEUTRALIZING AN ACID WITH A BASE.

Experiment 65. — Formation of a Salt. Place an evaporating dish on a tripod-stand. Pour in about 3^{cc} of dilute nitric acid, HNO_3.

Add ammonia solution gradually, constantly stirring with a stirring rod until the mixture is neutral. Test the neutrality (?) with litmus paper. If necessary, add minute quantities of acid if too alkaline, or ammonia if too acid.

When neutral, evaporate the contents of the dish gradually. Do not let the solution boil, as it drives off the ammonia.

What is the solid substance in the dish on evaporation? Complete the equation $NH_3 + HNO_3 = ?$

THE COMPOUNDS OF NITROGEN AND OXYGEN.

Experiment 66. — The Preparation of the Monoxide, N_2O. Arrange to collect two bottles of gas over water. Let one bottle be small. Place the apparatus on the tripod-stand and heat the water until it is hot to the hand, but not necessarily to the boiling point. Why? While heating the water, fit a test-tube with a sound cork and glass delivery tube.

Place in the tube a few pieces of fused ammonium nitrate, NH_4NO_3.

Remove the burner from beneath the pan, and heat the contents of the tube gradually until it melts. Now increase the heat enough to make the nitrate boil steadily.

As soon as it begins to boil place the delivery tube under the larger bottle and collect the gas evolved, only heating the tube enough to keep the contents boiling briskly. Collect the small bottle of gas.

Show by the equation that nothing would be left in the tube if heated sufficiently long. $NH_4NO_3 +$ heat $= ? + ?$

After the bottles of gas have been collected, replace the burner under the pan to keep the water hot, until the gas has been examined in the following experiment.

Experiment 67. — Properties of the Monoxide. Stand the small bottle, covered, upright on the table. Examine. (?) Remove cover and inhale the gas. (?)

So far, what class of properties has been observed, physical or chemical?

Remove the larger bottle. Plunge into the gas a glowing splinter of pine. (?) Compare the action with the result of Exp. 22. (?)

How may this gas be readily distinguished from oxygen? Which is the more active?

Experiment 68. — Preparation of the Dioxide, NO. Properties. Place in a generating bottle, fitted with a glass delivery tube, a few copper clippings. Arrange to collect one bottle of gas over water.

Cover the copper with water, and then add 1 or 2 ^{cc} conc. nitric acid, HNO_3. Collect the gas evolved.

Examine the gas in the generator. (?) Color? Does the color remain? Explain. Examine the gas collected. (?) Color? Explain what you see. Balance the equation $3\,Cu + ?\,HNO_3 = 3\,Cu(NO_3)_2 + ?\,NO + ?\,H_2O$.

Remove the bottle of gas, keeping the mouth of the bottle covered. Hold it before the window, for the sake of good light, and remove the cover. (?)

Where have the same fumes been seen before? Explain the action. What is the formula of the fumes? Balance the equation $2NO + O_2 = ?$

Experiment 69. — Preparation and Properties of the Trioxide, N_2O_3. Fit a test-tube with a cork and glass delivery tube.

Place in a small bottle on the table a weak solution of potassium permanganate, $KMnO_4$.

Fill the curved part of the test-tube with starch and add an equal volume of conc. nitric acid, HNO_3.

Heat the acid gradually and gently, avoiding scorching the starch and continually shaking the tube, until the starch dissolves. The heating may have to be continued a moment longer, but is generally unnecessary. (?)

As soon as action commences, insert the cork and delivery tube and pass the gas through the solution of permanganate. (?)

Carefully note the odor of the gas. (?) Compare color with the brown gas observed in Exp. 68. (?)

The action on the permanganate solution is a test for the gas. Try the decolorized liquid in the bottle, with litmus paper. (?)

Nitrous acid, HNO_2, is formed when N_2O_3 reacts with H_2O. Complete and balance the equation $N_2O_3 + ? = HNO_2$.

As soon as the work of the experiment is completed wash out the test-tube and flush the basin, as the gas is poisonous.

Experiment 70. — Preparation of the Tetroxide, NO_2. Place in a damaged test-tube a crystal of lead nitrate, $Pb(NO_3)_2$ and heat persistently in the hot flame. (?)

Compare the fumes given off with those observed in Exp. 68. (?) Examine the dry yellow powder remaining in the tube. (?) Is it the same as the substance labelled Litharge, PbO? Complete the equation $Pb(NO_3)_2 + \text{heat} = ? + ? + O$.

NITRIC ACID AND THE NITRATES.

Experiment 71.— Preparation of Nitric Acid from a Nitrate. Take about 1^{cc} of powdered potassium nitrate, KNO_3, in a test-tube. Add about 2^{cc} of conc. sulphuric acid, H_2SO_4.

Heat carefully. Examine the vapor arising in the tube. (?) Note the liquid running down the side of the tube. (?)

Have you a reason for thinking the vapor and liquid are of the same composition? Bring a drop of ammonia on a stirring rod over the tube. (?) A moistened strip of blue litmus paper. (?)

In case a brown vapor is seen, it is caused by the decomposition of the acid.

Equation: $2HNO_3 + \text{heat} = H_2O + 2NO_2 + O$.

Mention properties of nitric acid noted in this experiment: color, odor, normal condition, etc. (?)

Notice bottles of conc. nitric acid which have been exposed to strong light and compare with those unexposed. (?) Complete and balance the equation $KNO_3 + H_2SO_4 = K_2SO_4 + ?$

Experiment 72. — The Oxidizing Power of Nitric Acid. Take 2 or 3^{cc} of conc. nitric acid, HNO_3, in an evaporating dish, and warm it gently.

Drop into the acid a small piece of freshly cut phosphorus. Care must be observed in this experiment to avoid being burned by the slight tendency to explode. The phosphorus should be carefully dried with bibulous paper before using. (?)

In case white fumes are seen, give their formula. Compare Exp. 28. (?) To account for brown fumes, see Exp. 71.

If, in this case, the oxygen is in the nascent (?) state, explain how it differs from oxygen as examined in Exps. 26–9. (?)

Experiment 73. — Oxidizing Power continued. Take some powdered charcoal in an iron spoon, and hold in the hot flame until it commences to glow.

Now by the use of a clean stirring rod drop some conc. nitric acid upon the glowing charcoal. (?)

Equation: $5C + 4HNO_3 = 5CO_2 + 2H_2O + 4N$.

Does the equation account for the explosive action? Read something on gunpowder to confirm your answer.

Would you expect the result obtained, when reference is made to the action noted in Exp. 72?

Do you consider nitric acid a very stable compound? Give reasons for your answer.

Experiment 74.—The Oxidizing Power of a Nitrate. Heat charcoal again, just as in Exp. 73. Sprinkle powdered potassium nitrate, KNO_3, over the glowing charcoal. (?)

How does the action compare with that with nitric acid? Would you expect it from an examination of the formulæ of the two substances?

Would common salt, NaCl, act in the same way? Explain your answer.

Complete and balance the equation $5C + 4KNO_3 = K_2CO_3 + 3CO_2 +$? Compare the equation in Exp. 73. (?)

Note the white substance remaining on the spoon. It is potassium carbonate, K_2CO_3. Try it with moistened litmus paper. (?)

Experiment 75. — Dyeing with HNO_3. Dip a piece of white silk thread into very dilute nitric acid. Dry it by holding over the flame. Examine. (?)

What color is produced when you get nitric acid on your hands?

Experiment 76. — Nitric Acid and Vegetable Fibre. Prepare a small ball of common cotton, and one of gun-cotton, each about .5^{cm} in diameter.

Place the common cotton in a clean evaporating dish, touch a match to it, and watch it burn. (?) Anything left?

Now treat the gun-cotton in the same way. (?) Any difference? What causes the difference, if any?

What element has caused more rapid combustion in all these experiments?

How does gun-cotton differ from common cotton?

Experiment 77. — A Delicate Test for Nitric Acid or a Nitrate. Dissolve a small crystal of ferrous sulphate, $FeSO_4$, in about 5^{cc} of water.

Take in another tube a drop of the solution to be tested, and add about 3^{cc} of concentrated sulphuric acid, H_2SO_4.

Now pour, gradually, the ferrous sulphate solution upon the contents of the second tube, taking particular care not to let them mix. (?) Shake the tube. (?)

The brown ring is conclusive except in the presence of a compound of bromine.

Study the reaction: $2KNO_3 + 4H_2SO_4 + 10FeSO_4 = K_2SO_4 + 3Fe_2(SO_4)_3 + 4H_2O + 2(FeSO_4)_2 NO$. The last substance composes the brown ring.

Experiment 78. — Another Test for a Nitrate. Place a piece of copper in a test-tube, and pour over it about 5^{cc} of the solution to be tested.

Now add, a drop at a time, concentrated sulphuric acid until action is noted. Look down the tube. (?) Note the odor, if any. (?)

Compare color and odor with color and odor noted in Exps. 68 and 70. (?) Study the equations $2KNO_3$ $4H_2SO_4 + 3Cu = K_2SO_4 + 3CuSO_4 + 4H_2O + 2NO$; and $NO + O = NO_2$.

CHLORINE AND CHLORIDES.

Experiment 79. — Preparation of Chlorine from MnO_2 and HCl. Fill the curved part of the test-tube with manganese dioxide, MnO_2.

Pour over this about 2^{cc} of concentrated hydrochloric acid, HCl. Warm the mixture gently. (?)

Cautiously inhale a *little* of the vapor which arises. (?) Note color. (?)

Hold moist litmus paper over the mouth of the tube. (?)

Complete and balance the equation $MnO_2 + HCl = MnCl_2 + ? + ?$

Dry chlorine will not bleach dry litmus paper. Complete the equation and show that the bleaching is an oxidation process. $H_2O + Cl = HCl + ?$

Experiment 80. — Preparation of Chlorine from $KClO_3$ and HCl. Properties. Fill the curved part of the test-tube with $KClO_3$. Add 1^{cc} of HCl. (?) Compare Exp. 79. (?)

Attach a cork and delivery tube to the test-tube and let the gas bubble through some clear water for a moment. Examine the solution. Note color, odor, etc.

Add a drop of the solution to 5^{cc} of aniline solution in a tube. (?)

Make some marks with ordinary red ink on a piece of printed newspaper, place in an evaporating dish, and pour over it the remaining solution of chlorine in water. (?)

Printers' ink is mineral or inorganic; aniline red, organic. What statement may be made concerning the bleaching powers of chlorine?

Experiment 81. — Chlorine and Combustion. Generate chlorine in a test-tube by the action of hydrochloric acid on potassium chlorate. By means of a delivery tube pass the gas into a small empty bottle placed upright on the table and nearly covered by a glass slip.

When the bottle is full of gas, as indicated by the

color, plunge a lighted match or pine splinter into the bottle. (?)

Hydrogen has a strong affinity for chlorine. (?) Carbon is set free. Note the loss of color after the lighted stick has been placed in the bottle of chlorine.

Compare Exp. 22. (?) Show how they differ. Try a strip of litmus paper in the bottle after using the splinter. (?) Does chlorine support combustion?

Complete the equation $H_2 + Cl_2 = ?$

Does the litmus paper show the presence of an acid? When H burns in O, what is the product? Form the equation.

Experiment 82. — Preparation of HCl from Common Salt. Take in a test-tube about .5 gram of anhydrous sodium chloride, common salt, NaCl.

Add 1 ^{cc} of concentrated sulphuric acid, H_2SO_4. Heat gently. (?) *Very cautiously* inhale a little of the vapor arising from the tube. (?)

Compare the results of Exp. 79. (?) Bring ammonia on a stirring rod over the mouth of the tube.

Complete the equation $HCl + NH_3 = ?$ Hold a strip of litmus paper over the tube. (?) Compare Exp. 79 again. (?) Complete the equation $2NaCl + H_2SO_4 = ? + ?$

Note the white vapors coming from the tube at the outset of the experiment. (?) HCl is very soluble in cold water.

Experiment 83. — Test for HCl or a Chloride. Take 5 ^{cc} of the solution to be tested in a tube. Add a few drops of a solution of silver nitrate, $AgNO_3$. (?)

Divide the precipitate into two parts: To the first add a few drops of nitric acid. (?) To second, ammonia. (?)

It is necessary, in all tests, to remember that the color of the precipitate, and its solubility or insolubility in certain reagents, are distinguishing characteristics.

The presence of a chloride is proved by the fact that no other class of substances will act in the same way with the same reagents.

BROMINE AND BROMIDES.

Experiment 84. — Preparation of Bromine from a Bromide. Take in a tube, fitted with a cork and glass delivery tube, a crystal of potassium bromide, KBr; cover with manganese dioxide, MnO_2, and add 1^{cc} of conc. H_2SO_4. (?)

Attach the delivery tube to the generating tube, and put the end into a clean test-tube held upright in a tumbler of cold water. The bromine vapors condense on the cold sides of the tube. Note color, odor, effect on litmus paper, etc. (?) It may be necessary to heat the mixture slightly.

Balance the equation $KBr + MnO_2 + H_2SO_4 = MnSO_4 + HKSO_4 + H_2O + Br$.

Experiment 85. — Test for Free Bromine. The Ether Test. Place in a test-tube about 5^{cc} of the solution to be tested. Pour into this about 1^{cc} of ether. Shake the tube and let contents settle. Keep the mouth of the tube closed to prevent the escape of the ether.

Ether rises to the surface. Why? Any change in the color of the solution or ether? What and why?

From the color of the vapor in Exp. 84, what color would you expect for the ether in this case? Add a drop of potassium hydroxide, KOH. Shake. (?)

Experiment 86. — Test for Free Bromine. The CS_2 Test. Add to the solution of free bromine in a test-tube .5^{cc} of carbon disulphide, CS_2; shake vigorously and let settle.

The CS_2 does not mix with water, but, being heavier, sinks to the bottom of the tube.

Note color of the CS_2; also the color of the solution before and after treatment with CS_2. (?) Compare the ether test. (?)

Experiment 87. — Test for a Bromide. The Silver Nitrate Test. Take about 5^{cc} of the solution to be tested in a tube. Add two or three drops of a solution of silver nitrate, $AgNO_3$. (?) Compare the precipitate with that obtained in Exp. 83. (?) It should be a little more yellow. (?)

Shake the precipitate well and divide into three parts. Try the solubility of the precipitate in nitric acid. (?) In ammonia. (?) and in potassium cyanide, KCy. (?)

How does a test for a bromide differ from that for a chloride?

Experiment 88. — Test for a Bromide. The Chlorine Test. To 5^{cc} of the solution to be tested, add .5^{cc} of carbon disulphide. Shake. (?)

Add a drop of chlorine water. (?) Shake. (?) Continue to add the chlorine water by the drop, each time shaking the tube. (?)

Chlorides are more stable than bromides or iodides.

Complete and balance the equation $KBr + Cl = KCl + ?$ Compare Exp. 86. (?)

An excess of chlorine water will cause a disappearance of color, owing to the formation of the compound, $BrCl_3$. Account for the brown color produced on first adding the chlorine water.

IODINE AND IODIDES.

Experiment 89. — Preparation of Iodine from an Iodide. Treat a crystal of potassium iodide, KI, precisely as you did the bromide in Exp. 84, omitting the apparatus for collecting. Compare results with Exp. 84. (?)

Examine the crystals collected on the sides of the tube. (?) Heat them gently. (?) Compare Exp. 4. (?) Note odor and weight of the vapor. Touch the crystals with the finger. (?)

Experiment 90. — Test for Free Iodine. Treat the solution to be tested with CS_2 as in Exp. 86. (?)

How may iodine be distinguished from bromine?

Add a drop of the solution to 1^{cc} of starch solution. (?) See Exp. 46. (?)

Experiment 91. — Some Brilliant Iodides. Take about 5^{cc} of a solution of mercuric chloride, $HgCl_2$ in one tube; of silver nitrate, $AgNO_3$, in another; of lead acetate, $Pb(C_2H_3O_2)_2$, in another.

Add one or two drops of a solution of potassium iodide to each. Note the color of the precipitate in each. (?)

Complete the equations $HgCl_2 + KI = ? + ?$, $AgNO_3 + KI = ? + ?$, $Pb(C_2H_3O_2)_2 + KI = ? + ?$ Name the iodides formed.

Experiment 92. — Test for an Iodide. The Silver Nitrate Test. To about 5^{cc} of the solution to be tested add one or two drops of silver nitrate. (?)

The precipitate should have the same color and ap-

pearance as the second in Exp. 91. (?) Compare with the test for a bromide, Exp. 87. (?)

Divide the precipitate into three parts: Try in turn with nitric acid, (?) Ammonia, (?) and Potassium cyanide, KCy. (?)

Compare the results with those of Exp. 87. (?) How does the bromide test differ from the iodide?

Experiment 93. — Test for an Iodide. The Chlorine Test. Treat the solution exactly as in Exp. 88, testing for bromides. (?) Note difference. (?)

The colorless compound of iodine and chlorine has the formula ICl_3. Notice that the bromine and iodine tests and, in fact, many of their chemical characteristics, are similar.

Experiment 94. — Detection of Chlorides, Bromides, and Iodides in the same Solution. Preliminary Treatment. Take about 10^{cc} of a solution containing NaCl, KBr, and KI. Add two or three drops of $AgNO_3$ solution and shake the tube vigorously. (?) See Exps. 83, 87, and 92.

Continue to add the $AgNO_3$ by the drop, until no further precipitation occurs. The precipitate consists of AgCl, AgBr and AgI. Write the equations.

Filter and wash the precipitate well with hot water. The last washings should give no precipitate with HCl. (?)

Second Step. — Separation of the Chlorides from the Precipitate. Wash the precipitate into a clean tube through a hole in the bottom of the filter, using the least possible amount of water. Decant to 5^{cc}

Add 2 or 3 drops (not more) of a solution of KBr,

and boil for several minutes. The AgCl, only, is affected. Reaction: $AgCl + KBr = AgBr + KCl$.

Filter and test the filtrate for a chloride by Exp. 83. (?) The AgBr is insoluble, the KCl is soluble, and hence is found in the filtrate.

Third Step. — Separate the bromides from the iodides by treating the precipitate from which the chlorides have been removed with 3 or 4 drops of a solution of KI, as in the second step.

This time the reaction is $AgBr + KI = AgI + KBr$. The KBr is found in the filtrate on filtering, and is tested by Exp. 88. (?)

The iodides are identified by the yellow color of the remaining precipitate, and its difficult solubility in NH_4OH.

Fourth Step. — Another test for the bromides and iodides is applied directly to the original solution. It depends upon the difference in degree of the chemism of chlorine for the bromides and iodides.

Take 5^{cc} of the original solution. Add 2 or 3 drops of CS_2. Now add chlorine water, a few drops at a time, shaking in order to mix, and note the changes. Compare with the chlorine tests for bromides and iodides.

Note that the success of the test depends upon the gradual addition of the chlorine water. Which are more stable in the presence of chlorine, bromides or iodides?

Experiment 95. — Hydrofluoric Acid, HF, and Etching on Glass. (This experiment should be performed in the gas chamber by the instructor.)

Coat a piece of glass, by dipping into melted paraffin,

and standing it on edge to cool. The coat should be thin and smooth.

Trace with a pin or needle the desired figure, cutting through the paraffin to the glass. It is now ready for treatment with the acid.

Place in a lead dish some powdered CaF_2, fluorspar. Pour over it about 5^{cc} of conc. H_2SO_4, and suspend the glass, face down, over the dish, and as near as possible to it.

After the action ceases, warm the glass over the flame, and with a dry cloth wipe off the melted paraffin.

The design will be found etched into the glass. Equations: $CaF_2 + H_2SO_4 = CaSO_4 + ?$ and $SiO_2 + HF = SiF_4 + ?$ Complete and balance.

CARBON AND CARBON COMPOUNDS.

Experiment 96. — Some Properties of Charcoal. Arrange a filter paper in a funnel. Place on it a small spoonful of powdered charcoal. Pour on the charcoal about 10^{cc} of a solution of red aniline, and catch the filtrate in a clean tube. (?)

As soon as the solution has passed through, pour on the same or a fresh portion (the first will do) about 5^{cc} of a solution of potassium bichromate, $K_2Cr_2O_7$, and catch the filtrate in a clean tube. (?) The first is an organic color; the second, inorganic. (?)

Experiment 97. — Hydrocarbons. Methane or Marsh Gas, CH_4. Fit a test-tube with a cork, and a delivery tube fitted with a jet. Place in the tube about 5^{cc} of a mixture of 2 pts. of sodium acetate, $NaC_2H_3O_2$; 8 pts. of sodium hydroxide, NaOH; and 2 pts. of calcium oxide, CaO.

Heat the tube and contents carefully, but strongly and persistently, bringing the jet near the flame to ignite the gas which is evolved. Note the odor of gas (?) and flame. (?)

In this reaction is the calcium oxide changed? Compare with the action of manganese dioxide in Exp. 25. (?) Complete the equation $NaC_2H_3O_2 + NaOH = Na_2CO_3 + ?$

Experiment 98.—Hydrocarbons. Ethylene or Olefiant Gas, C_2H_4. Fit a test-tube as in Exp. 97. Place in it about 3^{cc} of alcohol and 2^{cc} of conc. sulphuric acid.

Heat the tube and contents carefully, bringing the jet near the flame as before. Compare the flame with that of Exp. 97. Complete the equation $C_2H_6O = ? + ?$

The acid is not decomposed. It is hygroscopic (?) and extracts water from the alcohol. Compare Exp. 18.

From an inspection of the formulæ CH_4 and C_2H_4, would you expect the difference in the flames of marsh and olefiant gases? Explain.

Experiment 99.—Destructive Distillation of Coal. Coal Gas. Place in a test-tube, fitted with a delivery tube and jet, a few pieces of coarsely powdered bituminous coal.

Strongly heat the tube and contents, noting changes which take place. (?) Care must be taken to hold the tube in a horizontal position, to prevent any moisture, which may condense on the cooler parts, from running down into the hotter part and breaking the tube.

Bring the jet near the flame, as in Exps. 97 and 98. (?) Collect a small bottle of the gas and test, as in Exps. 51 and 55. (?)

Experiment 100. — Destructive Distillation of Wood. Wood Gas. Treat a few thoroughly dried pine shavings in the same way that you did the coal in Exp. 99, taking the same precautions, and noting the same points. (?)

Experiment 101. — Detection of Ammonia, NH_3, and Hydrogen Sulphide, H_2S, in Coal Gas. Place on the top of the burner under a hood or in a strong draught, a strip of moistened red litmus paper and a strip of bibulous paper moistened in lead acetate solution. Close the holes at the base of the burner, and turn on the gas. A current of gas will flow out against the papers. (?) The ammonia, if present, will change the litmus. (?) The hydrogen sulphide will change the lead acetate to the sulphide which is black. (?)

Experiment 102. — Detection of Carbon Dioxide, CO_2, in Coal Gas. Place a small bottle on the table, add 10^{cc} of a solution of calcium hydrate, $Ca(OH)_2$ and fill with distilled water.

Remove the connecting tube from the gas burner. Insert a short glass tube and pass the gas slowly through the solution in the bottle.

If carbon dioxide is present the liquid becomes milky, calcium carbonate being formed.

Equation: $Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$. (?)

Experiment 103. — Carbon Monoxide, CO. Preparation and Properties. Place in a test-tube fitted with a cork and delivery tube with jet, a few pieces of coarsely powdered potassium ferrocyanide, K_4FeCy_6 with about 5^{cc} of conc. sulphuric acid.

Heat the tube carefully, and note the odor, color, etc. of the gas which escapes. Bring the jet near the flame. (?) Note the color, odor, and reaction of the products of the flame.

Does the gas evolved change blue litmus paper? Does the product of the flame change the paper? Complete the equation $K_4FeC_6N_6 + 6H_2SO_4 + 6H_2O = K_2SO_4 + FeSO_4 + (NH_4)_2SO_4 + ?$

Experiment 104. — Carbon Dioxide, CO_2. Preparation from $CaCO_3$ and HCl. Fit a generating bottle with a delivery tube, and arrange to collect four bottles of gas over water.

Place in the generator a few pieces of marble, calcium carbonate, $CaCO_3$; cover with water, and add enough conc. hydrochloric acid, HCl, to cause a rapid evolution of gas, which proceed to collect. Note color and odor of CO_2. (?)

When the gas has been collected, wash and save the remaining marble. Complete the equation $CaCO_3 + 2\,HCl = CaCl_2 + ? + ?$ The gas will be used in Exp. 105.

Experiment 105. — Carbon Dioxide, CO_2. Some Properties. (*a*) Place a bottle of CO_2 on the table, covered. Light a pine splinter, and introduce into the bottle. (?)

Repeat the experiment, keeping the bottle covered when possible. (?)

(*b*) Take a fresh bottle of CO_2, as in *a*, hold a strip of magnesium ribbon with nippers, ignite and introduce as before. (?) Compare the action. (?) Does CO_2 support combustion? Account for the presence of black particles found. (?) Compare Exp. 29. (?) Complete the equation $CO_2 + 2Mg = MgO + ?$

(*c*) Place a small candle upright in a common tumbler, near the side. Partly close the opening with the hand, and pour over the flame the contents of a bottle of carbon dioxide gas. (?) Is CO_2 a heavy gas? Why?

Experiment 106. — Carbon Dioxide, CO_2, continued. Pour into a bottle of carbon dioxide about 5^{cc} of calcium hydroxide, $Ca(OH)_2$. Cover quickly and shake vigorously, noting appearance from time to time. (?) Complete the equation: $Ca(OH)_2 + CO_2 = ? + ?$

Calcium carbonate is soluble in an excess of carbon dioxide. Does that explain the changes noted during the shaking? Try the solution in the bottle with litmus paper. (?) Moisten litmus paper with $Ca(OH)_2$. (?)

Experiment 107. — Carbon Dioxide, CO_2, exhaled from the Lungs. Place about 10^{cc} of a clear solution of calcium hydroxide in a test-tube. By means of a glass tube exhale air *from the lungs* so that it shall bubble up through the liquid. (?)

Compare with Exp. 106. (?) Is carbon dioxide exhaled from the lungs? Explain your answer.

Experiment 108. — Test for Carbonates. All carbonates effervesce (?) when treated with strong acids, such as hydrochloric and sulphuric acids.

Touch specimens of carbonates with a glass rod moistened with one of these acids. (?) What is the gas evolved? Compare Exp. 5. (?)

State the difference between common limestone and marble.

Experiment 109. — Cyanides. Carbon and Nitrogen. Test for a Cyanide. Take about 5^{cc} of the solution in a test-tube. Add about two drops of potassium hydroxide, KOH; then about three drops of a solution of ferrous sulphate, $FeSO_4$. Shake the tube, and acidulate (?) with hydrochloric acid. (?)

Prussian blue is formed if a cyanide is present. (?)

SULPHUR AND SULPHUR COMPOUNDS.

Experiment 110. — Amorphous or Plastic Sulphur. Take a spoon half full of flowers of sulphur. Hold in the hot flame and notice that it first melts to a clear liquid, then turns dark, thickens, and requires more heat to again melt it.

Heat strongly and quickly until the sulphur boils vigorously, and is thin enough to run. When sufficiently heated, quickly pour the molten sulphur into a dish of cold water. (?)

Examine the product. What does it resemble? Is it still sulphur?

Why is it called plastic? Lay the product away and examine to-morrow. (?) This experiment should be performed under the hood.

Experiment 111. — Sulphur Crystals deposited on Cooling. Heat common sulphur in a tube until it boils freely and pours easily. Now move so that the inside surface of the tube is coated with the molten sulphur and let it drain down.

As the cooling progresses, crystals of great variety of form accumulate on the sides of the tube.

Examine the sublimate collected about the mouth of the tube. (?) Compare with flowers of sulphur. (?) Examine some of the yellow powder under the microscope. (?) Is it sulphur?

Experiment 112. — Sulphur Crystals deposited from CS_2 Solution. Place on a watch-glass some flowers of sulphur. Pour upon the sulphur just enough carbon disulphide to dissolve it. Let the watch-glass stand until

the liquid has evaporated. (?) Examine with the microscope.

Draw in your note-book the outline of one of the crystals. Are the crystals transparent?

Experiment 113. — Hydrogen Sulphide, H_2S. Preparation and Properties. Fit a test-tube with a good cork and delivery tube with jet. Put in the tube three or four pieces of ferrous sulphide, FeS, and cover well with water.

Add conc. sulphuric acid cautiously until evolution of gas takes place freely. Odor? Color? Avoid inhaling much of the gas, as it is poisonous.

Bring the jet near the flame. (?) Color of flame? Note the odor arising from flame? Complete the equation $H_2S + 3O = ? + ?$ State the cause of the odor of the products of the flame.

Complete the equation $FeS + H_2SO_4 = ? + ?$ Try the gas with litmus paper. (?)

Experiment 114. — Test for a Sulphide in Solid State. Treat a small quantity of the powdered substance, on charcoal with sodium carbonate, before the blowpipe.

Now place the fused (?) substance on a bright silver or copper coin, and moisten with a drop of water. If a sulphide is present a black spot appears. (?)

Wash the coin with water, and if the black spot is persistent, drop upon it a small quantity of a solution of potassium cyanide. (?)

The explanation of the reaction is that the sulphide is changed to sodium sulphide, Na_2S, which, moistened in presence of silver or copper, forms silver or copper sulphide, which is soluble in KCy.

Experiment 115. — Sulphur Dioxide, SO_2. Preparation and Properties. Place in a test-tube fitted with a delivery tube a few copper clippings. Add about 5^{cc} of conc. sulphuric acid. Heat until a gas is evolved.

Pass the gas into a test-tube containing about 10^{cc} of water. Save the solution. Note properties of the gas, as color, odor, etc. As the gas dissolves, the bubbles become smaller. See Exp. 51.

Try the solution with litmus paper. (?) Complete the equation $SO_2 + H_2O = ?$ Compare the odor of the gas with that noticed in Exps. 21, 40, and 110. (?) Complete the equation $Cu + 2\,H_2SO_4 = CuSO_4 + ? + ?$

Account for the color of the solution in the generating tube. (?) See Exp. 58.

Experiment 116. — Sulphur Dioxide, SO_2. Bleaching Process. Moisten the petal of a rose or any colored flower with the solution of sulphur dioxide obtained in Exp. 115. (?) Compare with Exp. 79. (?)

Now place the petal in a weak solution of sulphuric acid for a moment; wash, dry, and warm. (?)

Show by comparison of equations that chlorine bleaches by oxidation, while sulphur dioxide bleaches by reduction:

Equations: $Cl_2 + H_2O = HCl + ?$ and $H_2SO_3 + H_2O = H_2SO_4 + ?$

Experiment 117. — Test for a Sulphate in Solution. Take in a tube about 5^{cc} of the solution. Drop into it barium chloride, $BaCl_2$. (?) Complete the equation $H_2SO_4 + BaCl_2 = ? + ?$

Try the white precipitate obtained, with nitric, hydrochloric, and acetic acids. (?)

Most sulphates are soluble in water. Barium sulphate is insoluble in water, and in acids; hence the test.

Experiment 118. — Hydrogen Phosphide, or Phosphine. This experiment should be performed in the gas chamber by the teacher, as the fumes are very poisonous.

Fit a 200 ^{cc} Florence flask with a cork and glass delivery tube. Place the flask on a sand-bath and pass the end of the delivery tube beneath the surface of water in a dish.

Pour into the flask enough of a strong solution of KOH (about 1 to 5), to cover the bottom of the flask to the depth of about ¼ inch.

Drop into the KOH solution three pieces of freshly cut phosphorus, about the size of a grain of corn.

Now add about .5 ^{cc} of ether; attach the cork and delivery tube, taking care that the end dips below the surface of the water in the dish.

Heat the sand-bath gradually until the contents of the flask boil briskly. The ether is vaporized, and drives out the air from flask and delivery tube; the hydrogen phosphide which is produced by the combined action of phosphorus, KOH and H_2O only coming in contact with air upon bubbling up out of the water in the dish. (?)

To stop the action safely, first remove the cork and delivery tube from the flask, then remove the flask from the sand-bath.

Complete the equation $4P + 3KOH + ? =$
$3KH_2PO_2 + ?$

Experiment 119. — Tests for Common Acids. Examine four liquids and four solids each containing one acid, either as free acid, acid or normal salt, using the following table:

A. — IT IS A LIQUID AND NEUTRAL.

Evaporate to dryness over a water bath. Proceed by B.

B. — IT IS A SOLID AND NEUTRAL.

Place some of the solid substance in a test-tube and add 1 ^{cc} of conc. H_2SO_4; note results as follows: —

1. *Rapid effervescence of an odorless, colorless gas.*

Try for a carbonate, Exp. 108; also pass the gas through a clear solution of $Ca(OH)_2$. White precip. indicates a carbonate. See Exps. 106 and 107.

2. *Slower effervescence of a gas possessing odor, but not color:*

(*a*) *Odor of rotten eggs.* Indicates sulphide. See Exps. 113 and 114.

(*b*) *Odor of burning sulphur matches.* Indicates H_2SO_3 or $H_2S_2O_3$. See Exps. 115 and 116.

(*c*) *Odor of peach blossoms.* Indicates HCy. See Exp. 109.

(*d*) *Odor of vinegar.* Indicates acetic acid, $HC_2H_3O_2$. Prove it is an acetate by dissolving the solid substance in H_2O, adding some Fe_2Cl_6 and boiling. A red solution of ferric acetate.

$Fe_2(C_2H_3O_2)_6$, whose color is destroyed by HCl is produced, in case the substance is an acetate.

(*e*) *An irritating odor* indicates HNO_3, Exp. 78; HCl, Exp. 83; or HF, Exp. 95.

3. *On warming gently, a gas having an irritating odor and a color* indicates HI, Exps. 89, 92, and 93; HBr, Exps. 84 and 88; or, HNO_2, Exp. 69.

4. *A crackling sound or sudden explosion* indicates $HClO_3$. See text for the production of chlorine tetroxide, Cl_2O_4. Shep., p. 101.

5. If none of these acids are found, try for H_2SO_4, Exp. 117.

C. — IT IS A LIQUID AND ACID: In this case it may be a free acid or an acid salt. Try the solution directly:

1. Try for a sulphate, H_2SO_4, by first acidulating with HCl and then proceeding as in Exp. 117.

2. Try a fresh portion with HNO_3 and a drop of $AgNO_3$: white prec. indicates HCl; yellowish white, HBr; yellow, HI; brown to black, H_2S. Try as in B for each in turn.

3. Try in order as in B for HNO_3, H_2CO_3, $HC_2H_3O_2$ and $HClO_3$.

NOTE. — The teacher should take care to use only the commonest compounds for the above tests.

COMMON METALLIC ELEMENTS.

GROUP I.

Lead, Silver, and Mercury.

Experiment 120. — Amalgams. (*a*) Take in a test-tube a small globule of mercury. Cover the mercury with a 1 to 5 solution of silver nitrate, $AgNO_3$. (?) Do not shake the tube.

(*b*) Place in a tube small pieces of copper, zinc, and iron. Cover them with a solution of mercurous nitrate, $HgNO_3$. After standing a few moments, examine. (?) Remove the metals. Wipe them with the finger. (?) Rub them a moment. (?) Which are permanently affected? Compare the two experiments, *a* and *b*.

Equations: (*a*) $Hg + AgNO_3 = HgNO_3 + Ag$. The crystals obtained are composed of Hg and Ag. (*b*) $2\,HgNO_3 + Zn = Zn\,(NO_3)_2 + Hg_2$. Copper and iron reactions are similar. Write them. In this case the mercury forms a coating on the metals, and no crystals.

Experiment 121. — Lead. Precipitation by Means of Zinc. Place in a test-tube a strip of metallic zinc. Pour over it about 5 ^{cc} of a solution of lead acetate, $Pb\,(C_2H_3O_2)_2$. Do not shake the tube. Note any changes. (?) Examine product carefully.

Wash thoroughly with water, remove from the tube, and scrape the deposit off the zinc. Save for testing in Exp. 123. Complete the equation $Pb\,(C_2H_3O_2)_2 + Zn = Zn(C_2H_3O_2)_2 + ?$ Explain the action.

NOTE. — Remember to pour all solutions containing silver into a receptacle kept on the table for the purpose. Also never pour mercury or mercury solutions into the sink.

Experiment 122. — Lead. Preparation from Galena on Charcoal. Place on a piece of charcoal about .1 gram of pulverized lead sulphide, galena, PbS. Cover with a little sodium carbonate, Na_2CO_3, and heat in the reducing flame before the blowpipe. (?)

Note appearance of globules. (?) Remove the globules and try hardness, malleability, etc.

Why did you use sodium carbonate? Give properties of lead noted.

Experiment 123. — Tests for Lead in Solution. Place the product of Exp. 121 in a tube; cover it with dilute nitric acid and warm. Why? As soon as action ceases dilute with about 10^{cc} of water.

Now divide the solution into five parts, and treat as follows: To one, add hydrogen sulphide. (?) To second, potassium bichromate. (?) To third, ammonium carbonate. (?) To fourth, potassium iodide. (?) To fifth, sulphuric acid. (?)

The precipitates should be black, yellow, white, yellow and white in order. (?)

Name the products and write the equations.

Experiment 124. — Silver. Precipitation by Zinc. Treat a strip of metallic zinc with about 1^{cc} of a solution of silver nitrate, just as in Exp. 121. (?) Compare results. (?)

Save the product as before, for use in testing for silver. Complete the equation $2AgNO_3 + Zn = ? + ?$

Experiment 125. — Silver. Precipitation by Chloral Hydrate. Take about 1^{cc} of silver nitrate solution in a tube. Add two drops of chloral hydrate solution, and make alkaline with a drop of ammonia.

Heat the tube, rolling it in the fingers until a bright coating appears. What is it? Chloral hydrate is a reducing agent. What action has taken place?

Since silver is soluble in nitric acid, suggest a good way to clean your tube. (?)

Experiment 126. — Silver. Tests for Silver in Solution. Dissolve the product of Exp. 124 in dilute nitric acid and add enough water to make about 10^{cc} of the solution. To one-half of the solution add about two drops of hydrochloric acid. (?) Compare Exp. 83. (?)

Divide the precipitate into two parts: Try one with nitric acid (?); the other with ammonia. (?)

Through the remainder of the solution of silver, pass hydrogen sulphide. (?) Divide the precipitate into two parts: Try one with potassium cyanide, (?); the other with conc. nitric acid. (?)

Experiment 127. — Mercury. Precipitation by Zinc. Treat a small piece of metallic zinc with about 1^{cc} of mercurous nitrate $Hg_2(NO_3)_2$ as in Exps. 121 and 124.

Compare the product with the corresponding ones with lead and silver. (?) May they be easily distinguished in this way? Complete the equation $Hg_2(NO_3)_2 + Zn = ? + ?$ Save the product for the test in Exp. 128.

Experiment 128. — Mercury. Test for "ous" Mercury in Solution. Carefully wash the mercury obtained in Exp. 127 and wipe and remove the zinc remaining. Dissolve the mercury in a little dilute nitric acid. (?) Make it up to about 5^{cc} with H_2O.

Add two or three drops of hydrochloric acid. (?) Filter the precipitate and wash on the filter with a few drops of ammonia. (?) Compare Exp. 126, first part.

What is the action and what the black substance produced? Could you distinguish silver and mercury in this way?

Experiment 129. — Separation of Metals of Group I. in the same Solution.

Part I. Take in a tube about 10^{cc} of the solution containing the metals. Add hydrochloric acid, by the drop, as long as a precipitate forms. Color?

Filter and wash the precipitate with a *little cold water.* Why not much H_2O? The filtrate may be thrown away. Why?

The precipitate is composed of the chlorides of the three metals. See Exps. 126 and 128, and remarks on the precipitation of lead by hydrochloric acid, in text.

Part II. Wash the precipitate *well with hot water*, and catch the filtrate in a clean tube. Lead chloride is soluble in *hot* water. Hence it will be found in the filtrate. The remaining precipitate will be disposed of in Part III.

Divide the filtrate into three parts; try with potassium bichromate, (?) potassium iodide, (?) and sulphuric acid. (?)

Precipitates should be formed in each case corresponding with those of Exp. 123. Does this prove sufficiently the presence of lead?

Part III. Place the filter with the precipitate *insoluble in hot water*, over a clean tube, and wash well with 2^{cc} or 3^{cc} of ammonia. See Exps. 126 and 128. (?)

The silver chloride dissolves and filters through, while the black deposit remaining on the filter is sufficient proof of the presence of mercury.

It remains to show that the silver is present in the filtrate. Add, by the drop, strong nitric acid until a change is noted. (?) Explain by reference to Exp. 126.

A reappearance of the familiar white precipitate of Exps. 83 and 126 is proof of the presence of silver.

GROUP II.

Arsenic, Tin, and Copper.[1]

Experiment 130. — Arsenic. Preparation from the Oxide. Make a small ball of arsenic trioxide, As_2O_3, with powdered charcoal and a drop of water.

Place the mixture in a tube closed at one end, made by heating the end of a short glass tube (about three inches long) in the gas flame until it melts and closes.

Heat carefully and strongly. Examine the inner surface of the tube. (?) Note the odor, if any. Do not inhale the vapor freely. (?)

Experiment 131. — Arsenic. Marsh's Test. Arrange to generate hydrogen by the action of pure zinc and dilute H_2SO_4, in a test-tube fitted with a delivery tube and jet.

Before adding the H_2SO_4, put into the tube with the zinc and water three or four drops of a solution of arsenic acid, H_3AsO_4.

Pour in the H_2SO_4 and pass the gas through the apparatus until air is entirely expelled. (?) Now light the gas issuing from the jet, and bring in contact with the flame a cold piece of porcelain. A bright gray-

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[1] For other metals of this and following groups, see Shepard.

NOTE. — As hydrogen arsenide is a highly poisonous gas, it would be safest to have only one generator, and that in the gas chamber. Any number of spots may be obtained from it.

ish spot or mirror appears on the porcelain. It is metallic arsenic.

Produce several spots and immediately stop the action by washing out the contents of the tube.

The action is thus explained: Nascent hydrogen acts upon the arsenic acid, producing a gas highly poisonous and inflammable, hydrogen arsenide, AsH_3. This gas burns along with the hydrogen evolved from the zinc and H_2SO_4, and when the cold porcelain surface is brought to the flame, the arsenic is cooled below the point of ignition and deposited as a mirror. Compare Exp. 33.

Proceed to test the spots as follows: (*a*) Moisten one with $(NH_4)_2S_2$; it turns yellow.

(*b*) Add a drop of HCl to another; it does not dissolve.

(*c*) Treat another spot with a drop of a solution of chlorine in KOH; it dissolves.

(*d*) To another add hot HNO_3; it dissolves clear. To the clear solution add a drop of $AgNO_3$; no change. Now allow vapor of NH_3 to come in contact with the solution; it turns brick red or yellow.

These tests completely identify the arsenic, as antimony, which also forms spots similar to the arsenic spots, gives slightly different results with the same treatment. Compare text on antimony.

Experiment 132. — Tin. Precipitation by Zinc. Treat a strip of metallic zinc with 5^{cc} of a solution of stannous chloride, $SnCl_2$, just as in the preparation of lead, silver, and mercury. (?) Compare Exps. 121, 124, and 127. (?) Mention any properties of tin noted.

Could crystals of lead, silver, and tin precipitated by

zinc be distinguished by their form, color, and general characters? Save the product to test for tin in the next experiment.

Experiment 133. — Tests for Tin. Remove the crystalline deposit obtained in Exp. 132 from the zinc; wash thoroughly with H_2O, and dissolve in the least possible amount of dilute HCl. Heat if necessary. Dilute with H_2O to 10^{cc}.

Take 5^{cc} of the solution in each of two tubes. To one add a drop of mercuric chloride, $HgCl_2$. If tin is present in "ous" condition, a white precipitate, which soon turns black, will follow; if in "ic" condition, no change. (?)

Through the second part, pass hydrogen sulphide, H_2S. A stannous salt yields a brown precipitate, SnS; a stannic salt, a yellow precipitate, SnS_2. What is the character of the solution, "ous" or "ic"?

Experiment 134. — Copper. Precipitation by Iron. Put a piece of bright iron wire in a test-tube, and pour over it a solution of copper sulphate, $CuSO_4$. (?)

Remove and examine the wire. (?) Give some properties of copper noted. Complete the equation $CuSO_4 + Fe = ? + ?$

Experiment 135. — Copper. Reduction on Charcoal. Treat some powdered copper sulphate on charcoal with sodium carbonate, in the reducing flame. (?)

It is difficult to obtain clear beads, but small particles of the red-brown mass resulting may be washed with H_2O, and dissolved in the least possible amount of dilute HNO_3. Color of the solution? Save this solution to test for copper in the following experiments.

Experiment 136. — Copper. The Bead Test. Prepare a borax-bead on a platinum loop, just as before. Dip the bead while hot into the solution to be tested, and heat in the oxidizing flame before the blowpipe.

If the copper is present the bead will be *green* while *hot*, *blue* when *cold*. (?)

Now heat the bead in the reducing flame. (?)

Experiment 137. — Copper. Tests in the Wet Way. Dilute the solution remaining from Exps. 135 and 136 to about 10^{cc}. Divide into three parts.

To one, add two to ten drops of ammonia until changes cease. (?)

Through the second, pass hydrogen sulphide. (?) Compare the two resulting products. Give a distinction between solutions and precipitates. (?)

To the third, add one or two drops of potassium ferrocyanide, K_4FeCy_6. If copper is present in small quantity, a reddish-brown solution is formed; if plentiful, a precipitate of the same color. (?)

GROUP III.

Iron, Chromium, Aluminum, Nickel, Cobalt, and Zinc.

Experiment 138. — Iron. Tests for "ous" and "ic" Salts in Solution. Both ferrous and ferric salts are tested by the same reagents. The condition of the salt is determined by the action of the reagents, producing results peculiar to each condition.

Prepare a solution of a ferrous salt by dissolving a small clear green crystal of ferrous sulphate, $FeSO_4$, in 10^{cc} of cold H_2O.

Divide into four parts. To the first add one drop of

potassium sulphocyanide, KCyS. (?) To the second, one drop of potassium ferrocyanide, K_4FeCy_6. (?) To the third, one drop of potassium ferricyanide, K_3FeCy_6. (?) To the fourth, add one or two drops of conc. HNO_3, and boil for a moment. Any change noticed?

When cool, divide into three parts and add a drop of the same reagents as before, noting carefully each result. (?)

Now treat a solution of ferric chloride, Fe_2Cl_6, with the three reagents, omitting the use of HNO_3. Compare with the preceding results. (?)

What effect does HNO_3 have on an "ous" salt of iron?

Devise a table for record of results so that a comparison will be easy. The equations are difficult.

Experiment 139. — Chromium. The Bead Test. Dip the hot borax-bead into a solution of potassium chromate, K_2CrO_4, or of potassium bichromate, $K_2Cr_2O_7$, and heat in the oxidizing flame before the blowpipe. Chromium colors the bead green. (?)

Experiment 140. — Chromium. Tests for Chromium in the Wet Way. Divide the solution into three parts. Through the first pass H_2S. (?) To the second add $Pb(C_2H_3O_2)_2$. (?) To the third, $AgNO_3$. (?)

The products should be in order, a green solution, a yellow precipitate, and a red precipitate. The two precipitates are $PbCrO_4$ and Ag_2CrO_4, lead and silver chromates.

Write reactions for these on the supposition that the chromium was present as potassium chromate.

Experiment 141. — Test for Aluminum in Solution. Take 5^{cc} of the solution to be tested. Add one drop of HCl. (?) Now pass H_2S for a moment. (?)

Should any change be produced up to this time it is caused by the presence of metals of the first and second groups, which must be thoroughly precipitated and filtered off before proceeding.

Boil to expel the excess of H_2S. (The tube should no longer smell of the gas.) In case first and second groups are known to be absent, the preceding steps may be omitted.

Add 1^{cc} to 2^{cc} of a solution of ammonium chloride, NH_4Cl, and then add ammonia, NH_4OH, a drop at a time, until on shaking the solution smells of ammonia.

The appearance of a white, gelatinous precipitate of aluminum hydroxide, $Al_2(OH)_6$ is proof of the presence of aluminum.

Experiment 142. — To Separate and Identify Iron, Chromium, and Aluminum in the same Solution. Take 10^{cc} of the solution, add two drops of HCl. Pass H_2S. Filter if necessary to remove Groups I. and II.

Boil until the solution no longer smells of H_2S. Add two drops of conc. HNO_3 and boil for a moment. (?) Compare Exp. 138. (?)

Add NH_4OH until the solution is alkaline. Now add 1^{cc} of NH_4Cl. (?) The precipitate contains $Fe_2(OH)_6$, $Cr_2(OH)_6$ and $Al_2(OH)_6$.

Colors red, green, and white. Filter and wash.

Make a hole in the bottom of the filter, and wash the precipitate through into a clean tube. Decant to 5^{cc}.

Add 1^{cc} of KOH and boil for some minutes. The $Al_2(OH)_6$ dissolves. Filter.

Treat the filtrate with HCl to acid reaction, then add NH_4OH and NH_4Cl as before. Aluminum hydroxide is precipitated. Compare Exp. 141.

The precipitate of iron and chromium hydroxides obtained above is now treated for iron and chromium as follows: One-half the paper with its precipitate is washed with dilute HCl. The precipitate dissolves. Test this for iron as in Exp. 138. (?)

The remainder of the precipitate with the accompanying paper is put on a piece of platinum foil, covered with a mixture of equal parts of KNO_3 and Na_2CO_3 and fused in the Bunsen flame.

On cooling it is found to be tinged yellow, caused by the oxidation of the chromium to the form of a chromate.

Remove the mass and dissolve in 5^{cc} of H_2O. Acidulate with acetic acid, and add one drop of lead acetate solution. (?) Compare Exp. 140. (?)

Experiment 143. — Nickel. The Bead Test. Dip the hot borax-bead into the solution, which will in most cases be greenish in color, and heat in the oxidizing flame before the blowpipe. The bead becomes brownish-red while hot, yellow when cold. (?)

This test is obscured by the presence of cobalt. See Exp. 145. The reducing flame produces a grayish color, owing to the reduction to metallic nickel. (?)

Experiment 144. — Nickel. Tests in the Wet Way. Take 5^{cc} of the solution to be tested; add two drops of NH_4OH. (?) The apple-green precipitate is $Ni(OH)_2$. Now add an excess of NH_4OH. (?) Compare the test for copper, Exp. 137. (?) Now add KOH. (?)

To a second portion of the original solution add KOH. (?) Compare the reactions with NH_4OH. (?)

Experiment 145. — Cobalt. The Bead Test. Dip the hot borax bead into the solution to be tested, and heat in the oxidizing flame. (?)

All cobalt salts produce blue beads. Compare Exp. 39. (?)

Experiment 146. — Cobalt. "Sympathetic Ink." Write on a piece of glazed paper with a solution of cobaltous nitrate, $Co(NO_3)_2$. (?) Allow to dry and then warm. (?)

Hydrated cobalt salts are pink in color; anhydrous salts are violet. Account for the changes noted.

Experiment 147. — Zinc. The Blowpipe Test. Powder the solid to be tested, mix with sodium carbonate, Na_2CO_3, and heat in the oxidizing flame before the blowpipe on charcoal. A coating of oxide will be formed around the assay, *yellow* while hot, *white* when cold. (?)

Touch the coating with a rod moistened with a solution of cobaltous nitrate, $Co(NO_3)_2$. Heat again in the oxidizing flame. (?)

The product is a pigment (?) and its production here is proof of the presence of zinc.

GROUP IV.

Barium, Strontium, and Calcium.

Experiment 148. — Barium. Flame and Spectrum Tests. Moisten a clean platinum wire with a strong solution of a barium salt and put into the non-luminous flame. (?) The predominating color of the barium flame is green.

Examine the flame with the spectroscope. (?) The sifting of the rays of different tinge reveals the presence of the other colors.

The bright yellow indicative of sodium is generally present in all spectrum tests.

Name and locate, with the assistance of the luminous scale, the bright lines of the barium spectrum.

Experiment 149. — Barium. Tests in the Wet Way. A soluble barium salt may be tested for as follows:

(*a*) To one portion of the solution add $K_2Cr_2O_7$ and NH_4OH. (?) Barium chromate, $BaCrO_4$ is yellow. (?) Compare tests for lead, Exp. 123. (?) This precipitate should be insoluble in $HC_2H_3O_2$. (?)

(*b*) To a second portion, add H_2SO_4. (?) Try its solubility in acids. (?) Barium sulphate is white. Compare test for a sulphate, Exp. 117.

Try to filter it. (?) Barium sulphate is difficult to filter, owing to the exceeding fineness of the particles.

(*c*) To a third portion add one drop of a clear solution of $CaSO_4$. (?) Compare the precipitate with that obtained in *b*. (?) It should be the same.

Experiment 150. — Strontium. Flame and Spectrum Tests. Treat a strontium salt solution precisely as in Exp. 148. (?)

Name and locate the bright lines.

Experiment 151. — Green and Red Fire. Mix intimately one part powdered barium nitrate, $Ba(NO_3)_2$, one part powdered potassium chlorate, $KClO_3$, and ¼ part flowers of sulphur. Ignite with a match. (?)

Repeat the experiment, using instead of the $Ba(NO_3)_2$, an equal quantity of powdered $Sr(NO_3)_2$. (?)

To what are the colors due? Why are the $KClO_3$ and sulphur used. (?)

Note. — Powdered shellac may be substituted for sulphur in Exp. 151.

Experiment 152. — Calcium. Flame and Spectrum Tests. Treat a calcium salt solution as in Exps. 148 and 150. (?)

Name and locate the lines.

GROUP V.

Potassium and Sodium.

Experiment 153. — Potassium. Its Affinity for Water. Carefully, by means of nippers, drop a piece of metallic potassium in water in a dish. (?) Look at the flame through a blue glass. (?)

All potassium salts and the metal itself color the flame violet. Try the water with litmus paper. (?)

Never handle potassium and sodium with the fingers. Why? Complete the equation $H_2O + K = KOH + ?$ Compare Exp. 49.

The color of the flame is caused by the heat of the reaction igniting the evolved hydrogen, which in turn vaporizes some of the potassium which burns with the characteristic color, forming an oxide, K_2O.

Experiment 154. — Potassium. Flame and Spectrum Tests. Try a potassium salt solution as before with the flame and spectroscope. (?)

Name and locate the bright lines.

NOTE. — The violet line is difficult to get.

Experiment 155. — Sodium. Comparison with Potassium. Drop a piece of metallic sodium into a dish of water. (?) Compare Exp. 153. (?)

Repeat the experiment, using hot water. (?) Is potassium more or less active than sodium? Explain.

Try the water with litmus paper. (?)

Why do sodium and potassium float on water? Compare properties of sodium and potassium.

Experiment 156. — Sodium. Flame and Spectrum Tests. Examine the sodium salt solution as before.

Name and locate the bright lines.

APPENDIX.

TABLE OF REFERENCES.

Reference Books.	Abbreviation.
Shepard's Chemistry	Shep.
Attfield's Chemistry	Att.
Fresenius's Qualitative	Fre.
Fresenius's Quantitative	Fre. Q.
Remsen's Briefer Course	Rem.
Richter's Chemistry	Rich.
Wagner's Technology	Wag.
Gage's Elements of Physics	Gage.
Dana's Text-Book of Geology	Da.

References by Experiments.

Exp. 1 — Fre. Q. P. 30.

Exp. 3 — Gage P. 9.

Exp. 4 — Att. P. 91.

Exp. 5 — Da. P. 27 and 31.

Exp. 6 — Gage P. 9 ; also Exp. 11.

Exp. 7 — Att. P. 36.

Exp. 8 — Att. P. 115 ; Shep. P. 317.

Exp. 9 — Att. P. 84.

Exp. 10 — Rich. P. 90 ; Fre. P. 4.

Exp. 11 — Fre. P. 15.

Exp. 12 — Fre. P. 5.

Exp. 13 — Fre. P. 8.

Exp. 14 — Att. P. 106 ; Fre. P. 9.

Exp. 15 — Fre. P. 11 ; also Exp. 149.

Exp. 16 — Shep. P. 9.

Exp. 17 — Shep. P. 10.

Exp. 18 — Shep. P. 172.

Exp. 19 — Shep. P. 11.

Exp. 20 — Shep. P. 325.

Exp. 21 — Att. P. 143.

Exp. 22 — Shep. P. 23.

Exp. 23 — Shep. P. 23 ; Rem. P. 41.

Exp. 24 — Att. P. 17 ; Rem. P. 10.

Exp. 25 — Explanation of the action of MnO_2 : It either remains unchanged or undergoes a double change acting as a carrier in freeing the $KClO_3$ of its oxygen. Such action has been called "catalysis."

Exps. 26, 27, and 28 — Shep. P. 25.

Exp. 29 — Shep. P. 317.

Exp. 30 — Shep. P. 27; Att. P. 23.

Exp. 31 — Shep. P. 27.

Exp. 32 — Shep. P. 27.

Exp. 33 — Wag. P. 618; Att. P. 30.

Exp. 34 — Rem. P. 51–3.

Exp. 35 — Gage, P. 145.

Exp. 37 — Shep. P. 28; Rich. P. 293; Rem. P. 199.

Exp. 38 —Shep. P. 29; Rem. P. 198.

Exp. 39 — Rem. P. 201; Shep. P. 282.

Exp. 40 — Rem. P. 52.

Exp. 41 — Rem. P. 196; Att. P. 23.

Exp. 42—Rem. P. 196; Att. P. 23.

Exp. 44 — Rem. P. 53; Att. P. 155, Note 1.

Exp. 45 — Shep. P. 31; Rem. P. 91.

Exp. 46 — Shep. P. 31.

Exp. 47 — Att. P. 86.

Exp. 49 — Shep. P. 35; Att. P. 94; Rem. P. 59.

Exp. 50 — Rem. P. 65; Shep. P. 37; Att. P. 20.

Exp. 51 — Att. P. 21.

Exp. 54 — Rem. P. 77.

Exp. 55 — Wag. P. 646.

Exp. 56 — Rem. P. 77; Shep. P. 40.

Exp. 57 — Shep. P. 35.

Exp. 58 — Rem. P. 72.

Exp. 59 — Rem. P. 127; Shep. P. 50.

Exp. 60 — Shep. P. 51; Rem. P. 131.

Exp. 61 — Rem. P. 139; Shep. P. 52.

Exp. 62 — Shep. P. 52.

Exp. 63 — Shep. P. 55.

Exp. 64 — Shep. P. 58.

Exp. 65 — Att. P. 94; Rem. P. 117.

Exp. 66 — Shep. P. 59; Rem. P. 157.

Exp. 67 — Shep. P. 60; Rem. P. 158.

Exp. 68 — Shep. P. 61; Rem. P. 158.

Exp. 69 — Shep. P. 63.

Exp. 70 — Shep. P. 64.

Exp. 71 — Shep. P. 67; Rem. P. 148.

Exp. 72 — Shep. P. 68; Rem. P. 152.

Exp. 73 — Shep. P. 69; Rem. P. 310; Wag. P. 148.

Exp. 74 — Shep. P. 69.

Exp. 75 — Shep. P. 69.

Exp. 76 — Wag. P. 160.

Exp. 77 — Shep. P. 70; Att. P. 285.

Exp. 78 — Shep. P. 70; Att. P. 286.

Exp. 79 — Shep. P. 92; Att. P. 29; Rem. P. 98.

Exp. 80 — Shep. P. 93 and 95; Rem. P. 101.

Exp. 81 — Shep. P. 96.

Exp. 82 — Shep. P. 97; Rem. P. 103.

Exp. 83 — Shep. P. 99.

Exp. 84 — Shep. P. 109; Rem. P. 237.

Exps. 85 and 86 — Shep. P. 110.

Exp. 87 — Shep. P. 110; Att. P. 268.

Exp. 88 — Att. P. 268.

Exp. 89 — Shep. P. 116; Rem. P. 240.

Exp. 90 — Shep. P. 117; Att. P. 271.

Exp. 91 — Shep. P. 118.

Exp. 92 — Shep. P. 119; Att. P. 271.

Exp. 93 — Att. P. 271.

Exp. 94 — Shep. P. 119; Att. P. 273.

Exp. 95 — Shep. P. 122; Rem. P. 243.

Exp. 96 — Shep. P. 130.

Exp. 97 — Shep. P. 132.

Exp. 98 — Shep. P. 133.

Exp. 99 — Shep. P. 135; Wag. P. 645.

Exps. 101 and 102 — Shep. P. 135.

Exp. 103 — Shep. P. 136.

Exp. 104 — Shep. P. 140.

Exp. 105 — Shep. P. 140 and 142.

Exp. 106 — Shep. P. 138.

Exp. 107 — Shep. P. 138; Rem. P. 181.

Exp. 108 — Da. P. 36–7.

Exp. 109 — Shep. P. 146; Rem. P. 205.

Exp. 110 — Shep. P. 158; Rem. P. 248.

Exp. 111 — Rem. P. 249.

Exp. 112 — Shep. P. 158; Rem. P. 252.

Exp. 113 — Shep. P. 160; Rem. P. 252.

Exp. 114 — Shep. P. 163.

Exp. 115 — Shep. P. 164; Rem. P. 257.

Exp. 116 — Shep. P. 166.

Exp. 117 — Shep. P. 173.

Exp. 118 — Shep. P. 197; Rem. P. 267.

Exp. 119 — Shep. P. 204–206.

Exp. 120 — Shep. P. 211; Att. P. 192.

Exp. 121 — Shep. P. 225.

Exp. 122 — Shep. P. 225; Rem. P. 365.

Exp. 123 — Shep. P. 228.

Exp. 124 — Shep. P. 229; Rem. P. 341.

Exp. 125 — Shep. P. 229.

Exp. 126 — Shep. P. 233.

Exp. 127 — Shep. P. 234.

Exp. 128 — Shep. P. 235.

Exp. 129 — Shep. P. 239.

Exp. 130 — Shep. P. 242.

Exp. 131 — Shep. P. 246; Rem. P. 271.

Exp. 132 — Shep. P. 252.

Exp. 133 — Shep. P. 253.

Exp. 134 — Shep. P. 259.

Exp. 135 — Shep. P. 261; Rem. P. 335.

Exps. 136 and 137 — Shep. P. 261.

Exp. 138 — Shep. P. 281.

Exp. 139 — Shep. P. 285.

Exp. 140 — Shep. P. 285.

Exp. 141 — Shep. P. 288.

Exp. 142 — Shep. P. 289.

Exps. 143 and 144 — Shep. P. 292.

Exps. 145 and 146 — Shep. P. 294; Att. P. 231.

Exp. 147 — Shep. P. 300.

Exp. 148 — Shep. P. 312.

Exp. 149 — Shep. P. 311.

Exp. 150 — Shep. P. 313.

Exp. 152 — Shep. P. 316.

Exp. 153 — Shep. P. 321.

Exp. 154 — Shep. P. 326.

Exp. 155 — Shep. P. 328.

Exp. 156 — Shep. P. 333.

TABLE OF WEIGHTS AND MEASURES.

ENGLISH WEIGHTS.

Avoirdupois Weight.

POUND.	OUNCES.	DRACHMS.	GRAINS.	GRAMMES.
1	16	256	7000	453.5926
	1	16	437.5	28.3495
		1	27.3495	1.7718
			1	.0648

Troy Weight.

POUND.	OUNCES.	PENNYWEIGHT.	GRAINS.	GRAMMES.
1	12	240	5760	373.2419
	1	20	480	31.1035
		1	24	1.5552
			1	.0648

METRIC MEASURES.

Measures of Weight.

1 milligram $^{\text{(mg)}}$ = 0.001 gram = about $\frac{1}{65}$ of grain.
1 centigram $^{\text{(cg)}}$ = 0.010 gram.
1 decigram $^{\text{(dg)}}$ = 0.100 gram.
1 gram $^{\text{(g)}}$ = 1.000 gram = 15.4323 grains.

Equivalents.

1 liter $^{\text{(l)}}$ = 1.0567 quarts.
1 quart = .9463 liters.
1 meter $^{\text{(m)}}$ = 39.3708 inches.
1 inch = 2.54 centimeters $^{\text{(cm)}}$.

A TABLE OF THE PRINCIPAL ELEMENTS.

	ELEMENTS.	AT. WT.	SYM.	VAL.	SP. G.	CONDITION.
Non-metallic elements, or those forming acids with *H* or *OH*.	Oxygen	16	O	2	1.105	Gas.
	Nitrogen	14	N	1, 3, 5	0.971	Gas.
	Chlorine	35.5	Cl	1	2.45	Gas.
	Bromine	79.8	Br	1	3.187	Liquid.
	Iodine	126.6	I	1	4.948	Solid.
	Fluorine	19	F	1	1.313	Gas.
	Carbon	12	C	4	3.5–.6	Solid.
	Sulphur	32	S	2, 4	2.05	Solid.
	Phosphorous	31	P	3, 5	1.83	Solid.
	Arsenic	75	As	3, 5	5.73	Solid.
	Chromium	52.4	Cr	4, 6	6.5	Solid.
	Hydrogen	1	H	1	.069	Gas.
Metallic elements, or those forming bases with *OH*.	Manganese	54	Mn	2, 4, 6	8.03	Solid.
	Boron	11	Bo	3	2.5 ?	Solid.
	Lead	206.5	Pb	2, 4	11.37	Solid.
	Silver	107.7	Ag	1	10.53	Solid.
	Mercury	200	Hg	1, 2	13.55	Liquid.
	Magnesium	24	Mg	2	1.74	Solid.
	Tin	117.7	Sn	2, 4	7.29	Solid.
	Copper	63	Cu	1, 2	8.95	Solid.
	Iron	56	Fe	2, 4	7.86	Solid.
	Aluminum	27	Al	4	2.6	Solid.
	Nickel	58	Ni	2, 4	8.9	Solid.
	Cobalt	59	Co	2, 4	8.5–.7	Solid.
	Zinc	65	Zn	2	7.15	Solid.
	Barium	136.8	Ba	2	3.75	Solid.
	Strontium	87.4	Sr	2	2.54	Solid.
	Calcium	40	Ca	2	1.57	Solid.
	Potassium	39	K	1	.87	Solid.
	Platinum	194.4	Pt	4	21.50	Solid.
	Sodium	23	Na	1	.978	Solid.

LIST OF CHEMICALS AND APPARATUS FOR THE COURSE.

Preparation of Reagents.

Aniline	A few particles in H_2O to required color.
$AgNO_3$	1 g. of the crystal salt to 40^{cc} distilled H_2O.
Alcohol	Use 95 %.
$Al_2K_2(SO_4)_4$	1 g. to 10^{cc}.
$BaCl_2$	1 g. to 10^{cc}.
$Ba(NO_3)_2$	1 g. to 10^{cc}.
$Ca(OH)_2$	Digest slaked lime in H_2O, and filter.
$Co(NO_3)_2$	1 g. to 15^{cc}. Use the crys. salt.
Chlorine water	Saturated solution of chlorine in H_2O. Protect from light.
Chloral Hydrate	1 g. to 20^{cc}.
$Cr_2K_2(SO_4)_4$	1 g. to 10^{cc}.
$CuSO_4$	1 g. to 10^{cc}.
$CoCl_2$	1 g. to 10^{cc}.
$C_2H_4O_2$	30%.
$CaCl_2$	1 g. to 10^{cc}.
$CaSO_4$	Saturated solution in H_2O.
$FeSO_4$	Make up as needed with distilled H_2O.
Fe_2Cl_6	1 g. to 10^{cc}. Use crys. salt.
HCl, dil.	Reagent strength 1 to 4 by vol. Equiv. to 8.5 % HCl.
HNO_3 dil.	1 to 3 by vol. Equiv. to 20 % HNO_3.

H_2SO_4, dil.	1 to 5 by vol. Equiv. to 25 % H_2SO_4. Pour the *acid* into the *water* carefully.
$HgCl_2$	Saturated Solution.
$HgNO_3$	1 g. to 20^{cc}.
H_2S	Prepare as needed, using Kipp generator or equiv. with FeS and commercial HCl dil. 1 to 1 by vol.
H_3AsO_4	1 g. to 50^{cc}.
$KMnO_4$	Strong sol. 1 g. to 10^{cc}; or, better, a saturated solution.
$KMnO_4$, dil.	1^{cc} of strong sol. to 200^{cc} H_2O.
KI	1 g. to 20^{cc}.
KOH	1 g. to 10^{cc}.
KCy	1 g. to 10^{cc}. Use cold water. Does not keep well.
KBr	1 g. to 20^{cc}.
$K_2Cr_2O_7$	1 g. to 10^{cc}. Use warm H_2O.
K_4FeCy_6	1 g. to 15^{cc}.
KCyS	1 g. to 15^{cc}.
K_3FeCy_6	Make up as needed, 1 g. to 15^{cc}. Does not keep.
K_2CrO_4	1 g. to 20^{cc}.
NaOH	1 g. to 10^{cc}. Allow to settle, and decant.
NH_4OH	Dilute conc. 1 to 3 by vol. Equiv. to 10% NH_3.
NH_4Cl	1 g. to 10^{cc}.
NaCl	1 g. to 10^{cc}.
$(NH_4)_2CO_3$	200 g. $(NH_4)_2CO_3$, 800^{cc} H_2O, and 209^{cc} NH_4OH.
$(NH_4)_2S$	Saturate NH_4OH with H_2S. Add NH_4OH to alkaline reaction.
$(NH_4)_2S_2$	Add a little flowers of sulphur to $(NH_4)_2S$.

$Ni(NO_3)_2$	1 g. to 20^{cc}.
$NiCl_2$	1 g. to 10^{cc}.
$Pb(C_2H_3O_2)_2$	1 g. to 20^{cc}.
Starch	Digest 1 spoonful in 300^{cc} cold water, and boil.
$SnCl_2$	Dissolve in least amount of hot conc. HCl. Dilute with H_2O, 1^{cc} to 20^{cc}, and keep in a bottle with a piece of metallic tin.
$SnCl_4$	Dissolve tin in aqua regia. Evaporate to dryness. Make up 1 g. to 20^{cc} or more dilute if desired.
$SrCl_2$	1 g. to 10^{cc}.
$Sr(NO_3)_2$	1 g. to 10^{cc}.

Touch Paper, made by dipping filter paper in strong solution KNO_3 and drying.

$ZnSO_4$	Saturated solution.
$ZnCl_2$	1 g. to 10^{cc}.

PURCHASING LIST.

	For 20 Pupils.
Alcohol	1 quart.
Ammonium Carbonate	¼ pound.
Ammonium Hydrate, conc.	4 pounds.
As_2O_3	1 ounce.
$Ba(NO_3)_2$	¼ pound.
Borax	½ pound.
Carbon Disulphide	1 pound.
Copper clippings	1 pound.
$CuSO_4$	¼ pound.
$CaCl_2$	¼ pound.
CaO	¼ pound.
CaF_2	2 ounces.
Cotton, common	1 ounce.
Cotton, gun	½ ounce.
Charcoal, powdered	1 pound.
Charcoal, sticks for blowpipe	20.
Coal, bituminous	¼ pound.
Ether	1 pound.
$FeSO_4$	¼ pound.
FeS, fused	1 pound.
HgO	½ pound.
Hydrochloric Acid, C.P. Sp. G. 1.20	6 pounds.
Hydrochloric Acid, com. Sp. G. 1.20	2 pounds.
Iodine, sublimed	⅛ ounce.
Iron Filings, very fine	½ pound.
KNO_3	½ pound.
KBr	2 ounces.
KI	2 ounces.
$KClO_3$	2 pounds.

K_4FeCy_6	¼ pound.
Lead, metallic	¼ pound.
Litmus Paper, red and blue	1 sheet each.
Mercury, metallic	1 pound.
MnO_2	½ pound.
Magnesium Ribbon	½ ounce.
Marble, White	2 pounds.
$NaCl$	1 pound.
NH_4NO_3, anhydrous	2 pounds.
NH_4Cl.	1 pound.
$NaC_2H_3O_2$	2 ounces.
Na_2CO_3	1 pound.
$NaOH$	¼ pound.
Nitric Acid, Sp. G. 1.42	3 pounds.
Plaster of Paris	¼ pound.
$Pb(NO_3)_2$	2 ounces.
PbS, powdered	1 ounce.
PbO	1 ounce.
Phosphorus	1 ounce.
Potassium, metallic	¼ ounce.
Potassium Hydroxide, sticks	1 pound.
Platinum Wire, for blowpiping	5 grams.
Platinum Foil	5 grams.
Starch	½ pound.
$Sr(NO_3)_2$	¼ pound.
Sodium, metallic	½ ounce.
Sulphur, roll	¼ pound.
Sulphur, flowers	1 pound.
Sulphuric Acid, Sp. G. 1.84	9 pounds.
Sugar, granulated	1 pound.
Zinc, sheet	1 pound.
Zinc, granulated, made by pouring melted lumps into H_2O.	2 pounds.
ZnS, powdered	1 ounce.

Order Chemicals not otherwise specified in 1 ounce packages. Use C. P. Chemicals and distilled water for solutions wherever possible.

Apparatus required for each Pupil.

1 Metric and English rule. — 1 foot.
6 Test-tubes, ⅝"×6".
1 Rubber delivery tube.
1 Glass delivery tube.
1 Piece of window glass 2" square.
1 Piece of blue glass 2" square.
1 Evaporating dish.
1 Pair nippers.
1 Watch crystal, diameter 2".
1 Small microscope.
10 Filters, 5".
1 Funnel, 2½".
1 Glass rod.
1 Small magnet.
1 Tin-box cover.
1 Pneumatic trough.
4 Wide-mouth 4 oz. bottles.
1 Wide-mouth 1 oz. bottle.
1 Narrow-mouth 4 oz. bottle.
1 Foot No. 18 iron wire.
1 Foot fine iron wire.
1 Combustion spoon.
2 Pieces white cardboard, 2" square.
4 Pieces glass tubing, ¼" diameter, 3" long.
1 Glass tumbler.
1 Paraffin candle.
1 Lamp chimney, Argand.
1 Strip zinc, 4"×1".
1 Blowpipe.
1 Piece of wire gauze, 4" square, iron.
1 Tripod or ring stand.
1 Test-tube holder.
1 Wash bottle.
Assorted rubber stoppers and corks to fit bottles and test-tubes.

SCIENCE.

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